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WHALES AND PLANKTON IN THE NORTH ATLANTIC

A CONTRIBUTION TO THE WORK OF THE WHALING COMMITTEE AND OF THE NORTH EASTERN AREA COMMITTEE

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Administrative Report.

In the autumn of 1923 the Norwegian Government appointed a Whaling Committee consisting of the undersigned members: J. Hjort (Chairman), H. H. Gran, H. Hauan, H. Krogh-Hansen and J. Rasmussen. With the sanction of the Norwegian Department of Trade this committee approached the British Discovery-Committee with a proposal that the two bodies should co-operate in making a scientific study of whaling and the physical conditions in the sea which govern the life and migrations of whales. The British Committee at once expressed its full approval of this plan of co-operation, and as a result of the negotiations which followed it was agreed that, to begin with, the best form of co-operation would be for the "Discovery" to study whaling in the Antarctic, especially as carried on from the Falkland Islands Dependencies, while the investigations under the administrative direction of the Norwegian Whaling Committee undertook similar work in the North Atlantic.

In accordance with this agreement a number of investigations have been carried out during the years 1924—1928, with the results set forth in the present volume. The expenditure in connection with these researches has been most generously met by the whaling companies which have been members of the Norwegian Whalers' Association during that period, viz.:—

A/S Tønsbergs Hvalfangeri by Director Hans Borge.
Bryde & Dahls Hvalfangerselskap A/S by Director Lars Christensen.
Hvalfangeraktieselskapet Vestfold by Directors Johan Rasmussen & Co.
Hvalfangeraktieselskapet Sydhavet by Directors Johan Rasmussen & Co.
Hvalfangeraktieselskapet Rosshavet by Directors Johan Rasmussen & Magnus Konow.
A/S Odd by Director Lars Christensen.
A/S Hektor by Directors F. Bugge and H. Krogh-Hansen.
A/S Ørnen by Director Søren L. Christensen.
Hvalfangerselskapet Norge by Directors Chr. Nielsen & Co. A/S and during the years 1924, 1925, 1926 and 1927.
Compania Ballenera Espanola Lda. by Directors S. F. Bruun & von der Lippe.

Further, two Norwegian scientific funds, "A/S Norsk Varekrigsforsikrings Fond" and "Statens Forskningsfond" made grants which proved very useful, particularly during the preliminary work of planning the investigations.

In the summer of 1924 the s.s. "Michael Sars", which had been lent by the Department of Trade, made a cruise to Davis Strait under the command of Dr. HJORT, the other members of the expedition being Professor H. H. GRAN, Mr. J. KROHN-NIELSEN, Mr. LEIF STØRMER, and Mr. TH. RASMUSSEN. Dr. A. C. HARDY, then of the "Discovery" Expedition, was also a member of the party for a short time. On this cruise a study was made of the stocks of fish met with, the movements of whales, and the pelagical conditions in Davis Strait, Baffin Bay, and on the voyage from Norway and back in the Norwegian Sea and the North Atlantic.

During the four succeeding years, 1925—1928, the investigations were confined to the waters off Möre on the west coast of Norway. Here we received valuable assistance from the whaling station at Aukra, the heads of this station, Mr. H. HALVORSEN, Mr. G. LOUS, and Mr. ANDR. INGEBRIGTSEN (the manager), placing all its resources at our disposal for our research work. The Department of Trade furnished us with a 60-foot motor vessel, the "Morild", which made a large number of voyages from the Romsdal Fjord out across the coastal banks to the Continental slope of the bank. In this way:—

4	lines	of	stations	were	worked	in	coastal waters in 1925
9	—	—	—	—	—	—	1926
6	—	—	—	—	—	—	1927
5	—	—	—	—	—	—	1928

and some of these were worked, with the assistance of whaling vessels from the above mentioned station, right out across the Atlantic Ocean Current. Mr. J. T. RUUD joined in all these expeditions, and spent a great deal of time at the whaling station; to him, therefore, the credit of carrying out our plan is largely due. In addition, Dr. HJORT and Dr. GRAN, Mr. BRAARUD, Dr. LØVENSKIOLD and Mrs. B. RUUD FØYN took part from time to time in the investigations.

In the summer of 1927 the Swedish Hydrographical and Biological Commission manifested their great interest in these researches by sending their own research vessel, the "Skagerak", to Möre to join in the work of investigation. While there, Captain in the navy K. L. SUNDE, Dr. ERIK MARTENS and Dr. O. NYBELIN made a number of hydrographical and biological researches which, as the following papers show, added supplementary material of the greatest value to the other work done.

The plan and progress of the investigations have been reported on at various times in both the committees set up by the International Council for the Study

of the Sea, namely the Committee for the North-Eastern Area and the Whaling Committee. Accordingly the present volume is connected with the activities of those committees as well. Reference should be made in this connection to the reports of the two committees in "Rapports et Procès-Verbaux" for the years 1926—1928.

The investigations also owe much to the collaboration during these years of the statistical investigation set on foot by the Norwegian Whalers' Association, which is reported on by Mr. S. Risting in a special volume (L) of the International Reports.

In concluding this report we desire to express, on behalf of all who have taken part in the work, our cordial thanks for the generous support that we have received from so many quarters, and especially from the Norwegian Whalers' Association.

Oslo, March 1929.

Johan Hjort. H. H. Gran. H. Hauan.

H. Krogh-Hansen. Johan Rasmussen.

WHALING AND FISHING IN THE NORTH ATLANTIC

BY

JOHAN HJORT AND JOHAN T. RUUD

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Introduction.

The purpose of this paper is to discuss in the light of the material at our disposal some old and still very interesting problems of the fishing and whaling industries in the North Atlantic. These problems are mainly connected with the distribution and habits of the species of fish and whales of economic importance, which are found along the slope of the Continental Shelf — a "facies" of the sea bottom affording very special and characteristic conditions for supporting a large community of living creatures.

Part of our material dates from the time of the extensive fishing experiments which were carried out in the Norwegian Sea, at the beginning of this century, by the s.s. "Michael Sars" in cooperation with a number of chartered fishing steamers and in close touch with other research steamers of the International Council. In the summer of 1924 the "Michael Sars" made a short cruise to the west coast of Greenland in cooperation with Norwegian fishing and whaling expeditions. And in the years 1925—1928 a series of small expeditions were carried out in the m.s. "Morild" off the coast of Møre. (See the administrative report to this volume).

In the two first chapters we intend to consider separately the two great areas lying west and east of Greenland; and in a subsequent third chapter we shall discuss the general conclusions which seem to follow from a comparison of the two areas.

By way of introduction it may be useful to remind the reader of the more important physical and chemical features of the two areas. For a more detailed consideration of the subject we would refer (1) to the monograph by Helland-Hansen and Nansen (1909), (2) to Professor Helland-Hansen's chapter in "The Depths of the Ocean", and especially (3) to the treatment of the hydrographical material from our cruises in Dr. Martens paper in this volume.

The two great systems of oceanic circulation, with which we have to deal in this paper, are especially interesting to the biologist because of the great similarities in their main physical and chemical aspects.

Both areas may be considered as vast bays extending northwards from the Atlantic. In both areas a transverse ridge or barrier marks off a deep pool or pond filled with cold masses of water which are more or less shut off from the circulation of the deep layers of Atlantic water. In both areas the influence of the earth's

rotation results in a current running north along the eastern shores and south along the western shores. In both areas the south-going current carries true polar water of a temperature at or below freezing-point. In both areas the inflowing

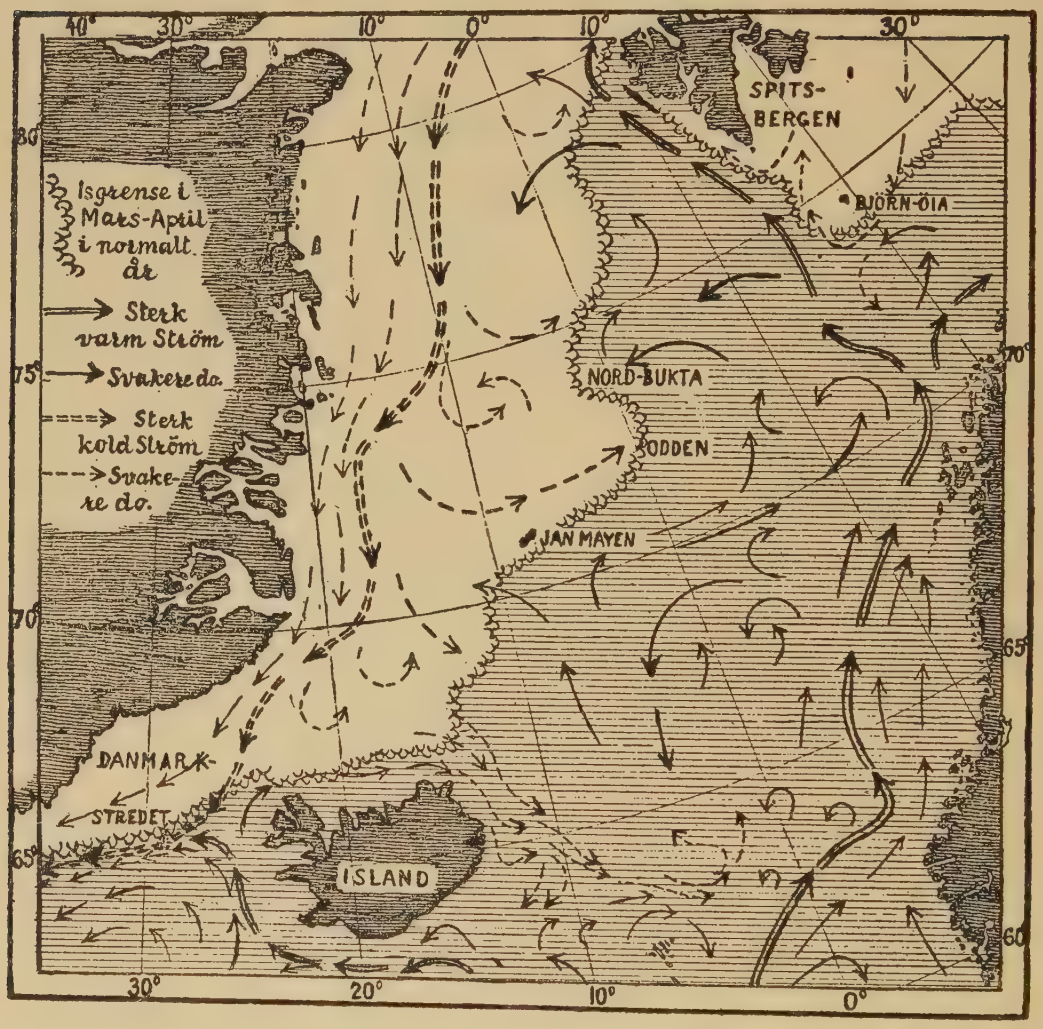


Fig. 1.

Atlantic water runs north-east, covering the slopes and at certain times of year the ground of the coastal banks outside the eastern coast line.

Besides these general similarities it may also be useful to bear in mind the important differences; especially in regard to the configuration of the static equilibrium of the system of currents, due partly to the general oceanic circulation of

the Atlantic and partly to the distribution of land and sea — or rather to the configuration of the sea bottom itself in these two areas.

The general system of the currents of the Norwegian Sea may perhaps be illustrated in the shortest and simplest way by referring to Fig. 1 and Fig. 2, the first taken from NANSEN (1924) and the second drawn by HELLAND-HANSEN for the "Depths of the Ocean".

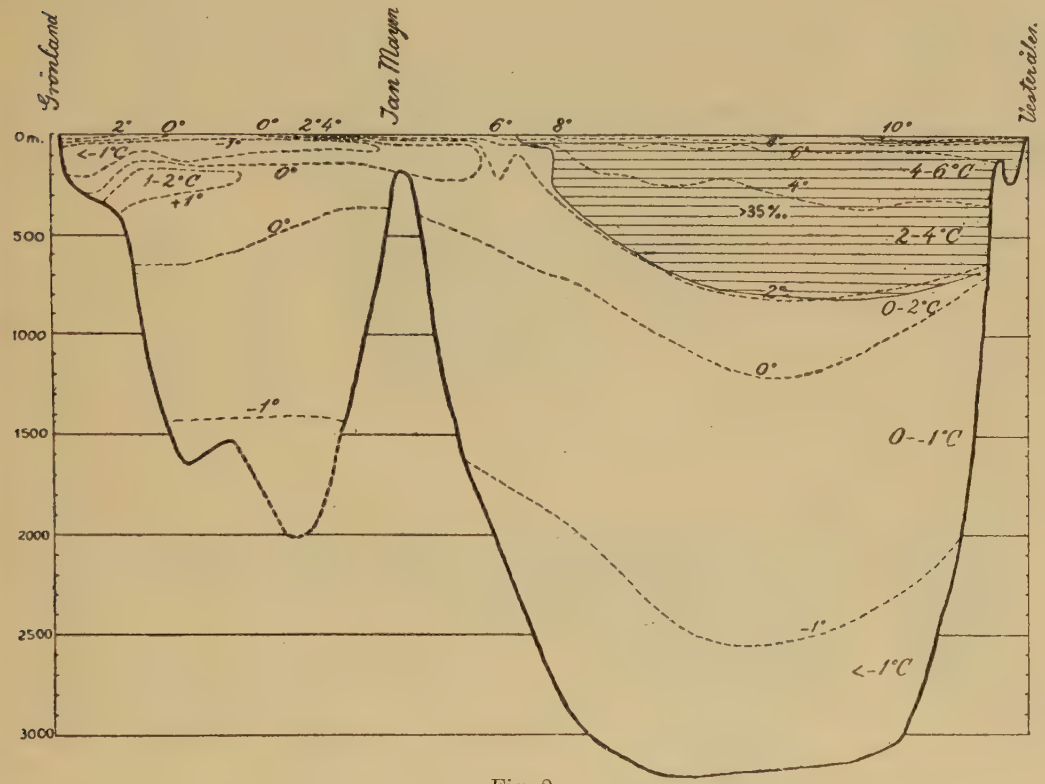


Fig. 2.

If we compare these two figures we can distinguish the coastal current coming from the Baltic and supplied with water from all the Scandinavian Fjords; the Atlantic current along the slope of the coastal banks; and the great western East-Greenland polar current, which also fills the great pool in the centre of the sea with its cold masses of water, having a temperature below freezing-point and a remarkably constant salinity of very nearly 35 ‰ (34.92 ‰). It is important to remember that the whole of this sea is to the north of the great barrier which stretches from Greenland via Iceland, the Faroes and Shetland to the North Sea. Accordingly the section shown in Fig. 2, which crosses the island of Jan Mayen, is also situated north of the barrier and is a real section of the pool at its centre.

If we compare these figures with our material from Davis Strait collected during the "Michael Sars" expedition 1924 it must at once be admitted that the material from this very short summer cruise is far less extensive than the material

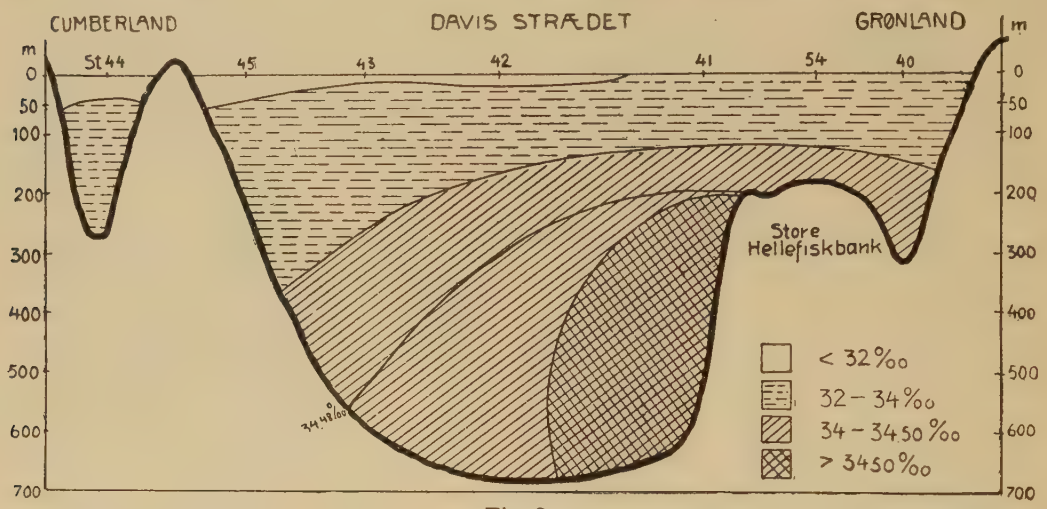


Fig. 3.

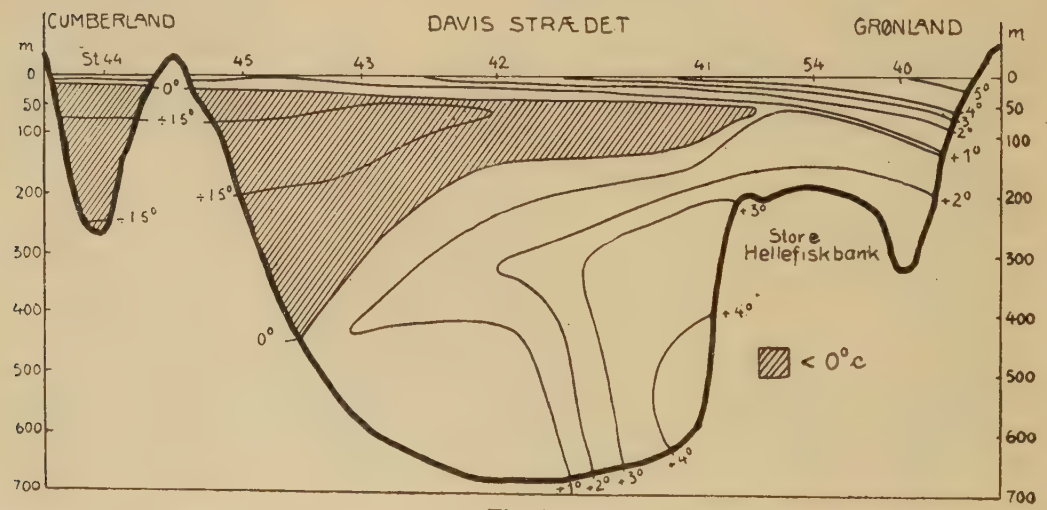


Fig. 4.

obtained from the Norwegian Sea. Nevertheless it may be of interest to consider, in this connection, the two sections (Fig. 3 and Fig. 4) which illustrate the situation in the summer (August 1924) in a cross-section just along the barrier, or rather along the actual ridge ot this barrier, which divides Davis Strait from Baffin Bay. The section is not directly comparable with Fig. 2 from the Norwegian Sea, which

is behind (north of) the barrier of that sea, but a comparison shows the important fact that the arctic current of the western area exercises an immeasureably greater influence than the south-going polar current of the Norwegian Sea. This is of course still more marked in winter time, when the whole of Baffin Bay is covered with floating ice, upon which seals and walrus are hunted even late on into the spring.

As in the case of the Norwegian Sea, the arctic current fills the deep pool of Baffin Bay. During the cruise of the "Michael Sars" a station (number 46) was taken just inside the deep part of Baffin Bay. The results of the physical and chemical observations at this station are of general interest both to the biologist and the oceanographer, so we give the particulars in the table below.

Table 1. "Michael Sars". Station 46. August 13th 1924. 67°19′ N. 58°52′ W. Depth 1335 m.

Depth metres	T°	S ‰	σ_t	O_2 cc	M %	P_H
1.....	÷ 1.35	30.75	24.74	8.01	94	8.10
10.....	+ 2.07	74	61	07	103	09
25.....	+ 1.43	33.10	26.51	13	104	19
50.....	÷ 1.23	49	96	7.71	92	00
75.....	÷ 24	64	27.08	43	89	7.97
100.....	÷ 04	73	14	11	86	94
200.....	+ 0.67	34.16	41	6.23	79	90
300.....	+ 98	36	55	5.79	74	85
500.....	+ 67	46	64	38	68	83
700.....	+ 49	48	68	08	64	82
900.....	+ 06	49	71	4.90	61	80
1100.....	÷ 0.22	48	72	66	58	78
1200.....	÷ 24	48	72	45	55	75
1300.....	÷ 29	49	72	20	52	76

If we compare the data from this station with the state of things in the Norwegian Sea, we find, in both cases, the most remarkable uniformity in all the great masses of water below the depth of the barrier (approximately 500 metres in both cases). The salinity and specific gravity are so uniform from this depth down to the bottom, that chemical analysis can detect no difference between one depth and another. The actual percentage of the salinity is not, however, the same in the two ponds. In Baffin Bay it is very nearly 34.5 ‰; in the Norwegian Sea 34.92 ‰.

This difference with regard to the actual percentage of salinity must, in view of the constancy of the results, be regarded as proof of the independence of the two areas; it may also prove that the influence of the melting ice is even more important in Baffin Bay than in the Norwegian Sea.

Of great interest are the figures for the content of Oxygen, the degree of the

water's saturation with oxygen, and the determination of the hydrogenion-concentration (P_H). All these figures prove the slowness, or at times the absence, of all water circulation in the deep water masses, where animal life has consumed as much as half of the oxygen once present in the water. Similar conditions have been found to exist in many Norwegian Fjords.

The north-going coastal current of Davis Strait and Baffin Bay differs from the Baltic current of the Norwegian Sea in the considerably lower temperature and perhaps also in the different chemical composition of its waters. The Baltic current coming from many fertile countries of Northern Europe may, in some years, have a very low temperature and derive its origin not only from fresh water out of the rivers of these countries, but from melting ice in the Baltic or even the Skager Rak. At most seasons of the year, however, this current is warmer than the eastern coastal current of Davis Strait, where a great many icebergs may be seen floating even in summer. The eastern coastal current of Davis Strait is a direct continuation of the East-Greenland polar current from the Norwegian Sea. Nevertheless, there are summer temperatures up to 6° C. in this current on the banks off the West-Greenland shores.

The Atlantic current of a salinity above 35 $^0/_{00}$ running into the Norwegian Sea (Figures 1 and 2) is, in its main configuration, determined by the depth of the Faroe-Shetland Ridge. Off the coastal banks of Norway it covers the slope to a depth of about 500 to 700 metres, corresponding to the depth of the Faroe-Shetland Ridge. The variations in the form of this current seem to be small and may depend mainly on the energy or speed of the current. Fishing experiments have shown that this feature has an all-important influence on the distribution of animal life belonging to the different communities, all the boreal species — and among them all the important food fishes — being confined to the area over which the warm Atlantic water is distributed.

South of the Faroe-Shetland Ridge, in the water between the British Isles and the Southern Faroe Bank, the conditions are quite different; Atlantic water and Atlantic temperatures of 6°—10° C. are still to be found there even at a depth of 800—1000 metres.

The western side of the North Atlantic has at present been very little investigated, or at any rate the results of such investigations are not yet available for comparison. The deep Atlantic water is here to a great extent mixed with the sinking masses of the Labrador current, which is the continuation of the cold south-going current of Davis Strait (Fig. 3 and 4). Nevertheless the "Michael Sars" expedition in 1924 found a layer with a temperature of nearly 4° C. (3.6°) and a salinity of 34.87 $^0/_{00}$, as far down as a thousand metres, outside the south-western slope of the Greenland coastal banks (see the hydrographical tables appended to Dr. MARTENS' paper, especially station 58).

This fact is of the greatest importance for understanding the distribution

of boreal animals and fishes in Davis Strait. A warm Atlantic current with a temperature of nearly 4° C. washes the slopes of all the coastal banks off the Greenland coast of Davis Strait right up to the barrier of Baffin Bay; and within this bay an intermediate current with a temperature of 2°—3° C. may be observed as far north as the bay of Disco. In this current, which may vary very considerably according to the season, and also be of very varying strength in different years, we have an important factor governing the fluctuating biological phenomena of the area.

Chapter I.

The Greenland Waters.

A. Fisheries off the West Coast of Greenland.

Historical Remarks.

Sealing, whaling and fishing have for nearly a thousand years been a subject of vital importance and of the keenest interest to all the colonists who have tried to make a living on the shores of Greenland.

The first settlers, who were emigrants from Norway, tried for a period of no less than 500 years (from the year 985 to the beginning of the 16th century) to transplant and maintain the civilization of their native country on the south-western shores of Greenland.

Agriculture must have been the first and main industry of these colonists, but fishing may gradually have increased in importance. Adolf Jensen (1925) gives the following interesting description of the conditions in the first district colonized:

"Some of the best spots for shark and Greenland halibut were located close to the sites which had been most populated in the time of the ancient Norsemen, to wit, the country on either side of Tunugdliarfik and that between Amitsarsuk and Igaliko fjord. I took the opportunity of visiting one of these places Kagsiarsuk in Tunugdliarfik, where Brattahlid, the homestead of Eric the Red is believed to have stood, and I was, like other travellers, astonished to find the vegetation so luxuriant, despite the fact that the land has lain fallow for 500 years and shrubs and undergrowth have been allowed to spread unhindered. Even to this day there are it would seem, remarkably favourable conditions for the keeping of livestock on a rational system, with proper treatment of the soil."

The history of this, the first colonization of Greenland, seems to support the view, now held by most historical writers, that the white man can only live in this country if he is able to import various vital necessities: materials for building houses and boats, and for making clothes and fishing and hunting gear; also supplementary provisions, such as grain, vegetables and fruit.

From this point of view it can only excite our admiration and wonder that an isolated civilization could be maintained in this arctic, far-off land for such a long period.

An import must either be balanced by an export of corresponding value or be subsidized by an interested, far-seeing and generous government. Taking into account the difficulties in the way of navigation and the exchange of goods in those ancient times, and the lack of interest shown by the governments of those days, it is by no means surprising that the attempt ended in failure.

When the Norwegian colonization came to an end a gradual immigration

Fig. 5. Eskimos in Kayaks, from JENSEN.

of Eskimos took place, starting from the north-western, and slowly proceeding towards the south-western shores of Greenland. The Eskimos had by that time long since developed their own "technique" for self-supporting life in the arctic; they were able to make their gear for hunting seals and even whales of the smaller species, and could supplement this, the most important part of their activities, by some primitive means of fishing in fjords or in the waters nearest the coast.

The life and methods of work of the Eskimos have been studied and described with sympathetic understanding by several authors, especially FRIDTJOF NANSEN and ADOLF SEVERIN JENSEN. In particular we would refer the reader to Professor JENSEN's most interesting paper (1925), which describes the circumstances as he found them on his expeditions at different times in the last twenty years.

One may say that the whole "technique" of the Eskimos consists in using the materials furnished by his own catch, above all the seals, for making his gear. Even the most essential part of his equipment, his boat (the kayak) is made out of these materials.

Admiration for the independent and self-supporting life of the Eskimos, coupled, perhaps, with the memory of the white man's failure to adapt himself to circumstances in this arctic region, inspired the idea that the Eskimo should be protected from all outside influence and that Greenland should be closed to all foreign settlement, trade and navigation.

This idea, and all the arguments put forward in its defence, have now, however, become out of date. The revival of navigation, owing *inter alia* to the great development of the old whaling industry, aroused even at the beginning of the 18th century, fresh and keen interest in the white man's activities in Greenland. From Norway a new settlement bearing a new civilization was transplanted to Greenland in the 18th century, and during the last hundred years great efforts have been made by the Danes to develop, that is, to alter, the original self-supporting industry of the Eskimo and help him to import the more necessary goods, which might once have saved the white man's civilization.

Further, international events of far-reaching importance have made their influence felt along the coast of Greenland, proving that the problem of preserving the manner of life of the Eskimos could not be solved even by the strictest measures to exclude foreign influence and industrial undertakings from the country.

The main industry of the Eskimos has from the first been the hunting of different species of seals, particularly the Greenland seal (*Phoca groenlandica*, O. Fabr.) and the hooded seal (*Cystophora cristata*, Erel). These two very important species are, however, by no means confined to the coast of Greenland. The individuals found there do not spend their whole lives there. On the contrary, it may be said that they only pay short visits to Greenland territory and pass most of their life in long migrations.

In a recent book (1924) of importance in its bearing on arctic questions Nansen has given a general survey of the migrations and the life of the shoals of these species of seal. Figure 6, copied from his book, will furnish the most concise guide to the migrations and breeding places of the Greenland seal. On the breeding ground this species is caught in enormous numbers, far exceeding the total caught by the Greenland Eskimos. According to the statistics given by Thor Iversen (1927) the Newfoundland sealing industry, which catches both the Greenland and the hooded seal, has for more than 200 years been taking enormous numbers, varying from 50,000 to over 500,000 a year. In the area off the east coast of Greenland (the Jan Mayen and Denmark Strait region) varying numbers up to 120,000 have been taken in one year. By way of comparison it may be stated that the catch of all kinds of seals in Greenland waters has been estimated at about 30,000 a year.

A similar state of affairs may be said to have arisen in the other old Eskimo industry, whaling. Here a distinction must be made between the old and the modern whaling industry. The old whaling dealt with the right whales, i. e. the Greenland whale (*Balaena mysticetus* L.) and the Nordcaper (*Balaena biscayensis*, auctt).

As early as the 16th century the old whaling industry was extended to the western part of the North Atlantic, whalers from the Bay of Biscay fishing outside the banks of New Foundland and Labrador. But it was not till the beginning of the 18th century that whaling in Davis Strait and Baffin Bay assumed any importance. In the years 1719 to 1729 Holland sent 748, and in the years 1729—1738, 975 whaling ships to Davis Strait. It has been calculated that when this industry was at its height the yearly catch amounted to a couple of thousand Greenland whales off

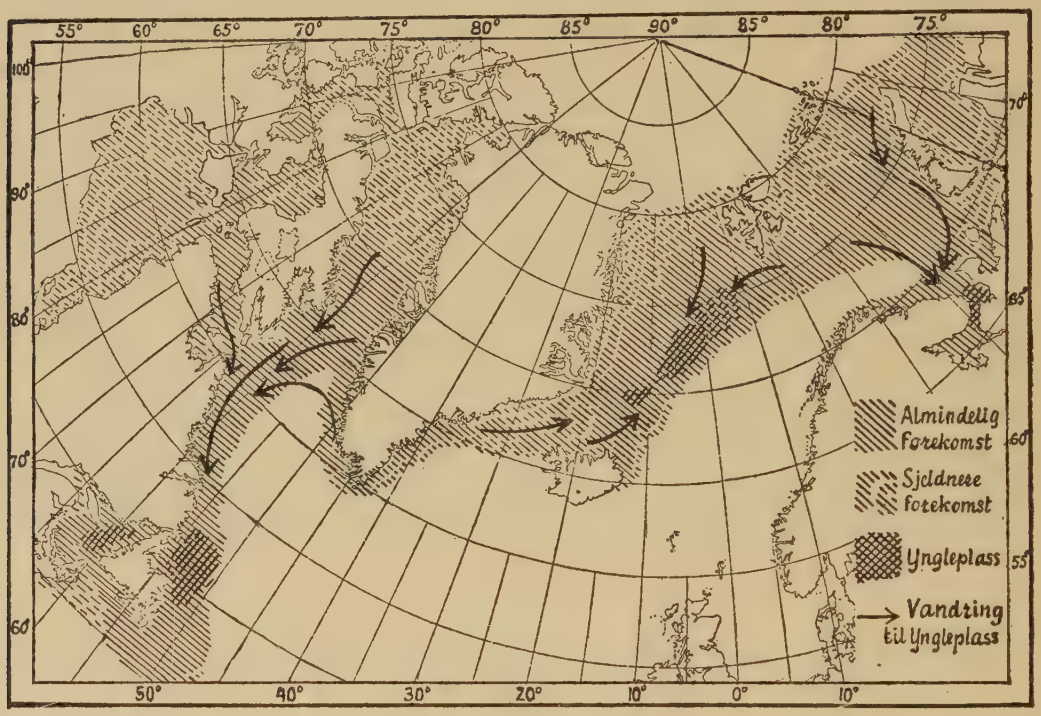


Fig. 6.

the east and some hundreds off the west of Greenland. The industry continued on a small scale until the commencement of the great war. "In former years great numbers were caught from the Danish whaling stations and also by the Eskimos, but as a result of over-fishing the species disappeared from the coasts of Greenland. In the last few years single whales have, however, been observed again." (Grønland Vol. I Copenhagen 1921.)

The modern whaling industry, catching fin-backs, will be discussed later. It was never of any importance to the Eskimos, who now confine their attentions to the whitefish (*Delphinapterus leucas* Pallas) and the narwhale (*Monodon monoceros* L.).

Even this short review of the most important historical facts will show

that the idea of restricting the Eskimo to his old industries of sealing and whaling is untenable. Much credit, therefore, is due to Professor Adolf Jensen for his great and successful efforts to improve the methods and extend the industrial activities of the Eskimo. "My ideal of a Greenlander is a man who goes a-sealing when there are seal to be had, and fishing when there are fish" was the leading idea of Jensen's fishery work in Greenland, which we will now proceed to consider.

Fishing Experiments.

In the summers of 1908 and 1909 Jensen made two cruises in the brig "Tjalfe" and in these years the whole western coast from 60° to 71° N. was covered, i. e. almost the whole of the colonized region comprising the fjords, coast, banks and deep sea.

Along this enormous distance the distribution and biology of all the more important edible fishes were investigated. The chief species are: The cod (*Gadus callarias* L.), the Fjord cod (*Gadus ogac* Richardson), the halibut proper (*Hippoglossus vulgaris* Fleming), the Greenland halibut or black halibut (*Reinhardtius* (*Platysomatichthys*) *Hippoglossoides* Walb), the long rough dab (*Hippoglossoides* (*Drepanopsetta*) *platessoides* O. Fabricius), two species of catfish (*Anarrhicas lupus* L. and A. *minor* Olafsen) and finally the Greenland shark (*Somniosus microcephalus* Schneider).

Jensen's investigations (1909) proved that the most important of these species — the cod, the halibut and the black halibut — were present in considerable quantities over a much larger field, i. e. a greater number of fjords than were previously known. He further established the fact that the very limited fishery was due to the exceedingly primitive equipment for fishing possessed by the fishermen, and equally to the difficulty experienced by them in disposing of their catch. Accordingly he worked out with the Danish Government a plan for providing the fishermen with dories or motorboats, organising the preservation (i. e. the salting, drying and tinning) of the catch and developing the market for the fishermen's products.

The result of this work was a considerable increase in the fishing industry of Greenland. The quantities of salted or dried cod sold by the Greenlanders varied in the period 1912—1916 from 23.5 to 124.5 tons a year and in 1917—1925 from 243.5 to 956 tons a year. It rose in 1926 to 2055 tons, and in 1927 to 3291 tons. In 1926 270 tons of halibut were sold to the local authorities.

During the expeditions of the "Tjalfe" in 1908 and 1909 several fishing experiments were also made on the coastal banks off the Greenland coast, but without success. The cod and halibut seem to have been absent, or in very small numbers, on the banks during the fishing experiments carried out in these years.

Fishing experiments on a large scale have previously been made with varying

results. JENSEN (1925) has collected the following information about the previous expeditions.

"In 1845, two English fishing schooners appeared on the banks, and during the following years, especially 1848 and 1849, more vessels arrived, but hardly exceeding ten a year. In 1848, the fishery was successful, but in the very next year it fell off considerably, and in 1850 and 1851, fish were so scarce that the fishery could not be made to pay. The cod fishery, then, could not be made a profitable undertaking for any length of time owing to the irregular appearance of the fish on the grounds. But since 1866, American fishing schooners have regularly made their appearance outside Holstensborg in pursuit of halibut; this lasted until the

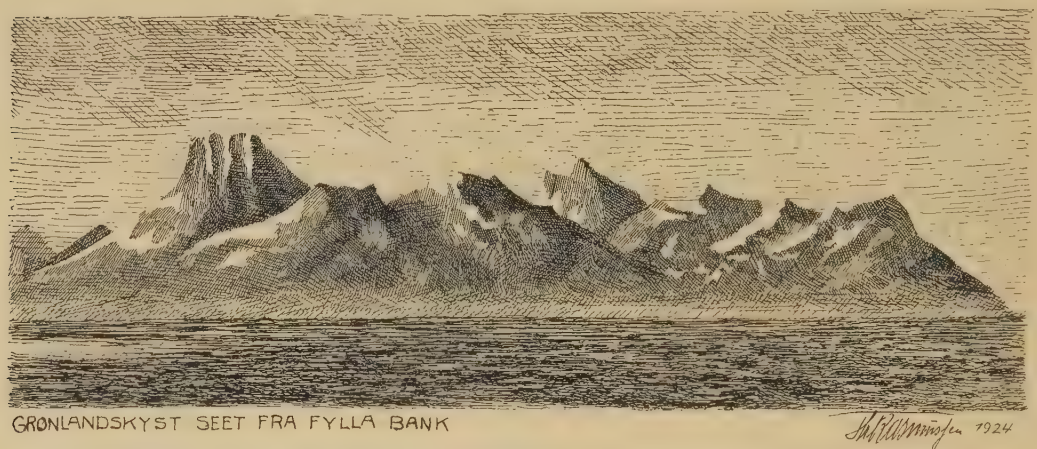


Fig. 7.

nineties, when it was discontinued, owing, it was said, to the heavy duty imposed in America on salted halibut from Greenland".

During the last few years Norwegian schooners sealing or whaling in Davis Strait or Baffin Bay have occasionally tried the hook on the coastal banks of these waters and many reports of good catches have reached Norway of late years. Of special interest was the information brought home by the well-known sealer Captain JOHAN P. K. OLSEN of Aalesund, who in the summer of 1922 made considerable catches on the banks.

When, therefore, HJORT was planning the "Michael Sars" expedition of 1924 to Davis Strait he suggested to leading owners in Aalesund that the stock of fish on these banks should be investigated by their joint efforts. This was carried out, with the result that extremely large quantities of cod and halibut were found on the southern banks.

After a stormy passage in fog and among a great number of icebergs the "Michael Sars" arrived on the Fyllas bank on August the 5th, 1924. The

following quotation from HJORT's diary illustrates the fishing conditions on the bank:

"On station No. 33 (63°55′ N. and 53° W.) at a depth of 67 metres the following temperatures were observed:

Surface 6.09°, 10 metres 6.20°, 25 metres 1.95°, 50 metres 1.20°, 60 metres 1.55°.

Fishing with 2 or 3 handlines 70 large cod, and 1 halibut were taken in the course of about half an hour. The cod were near the bottom (1 or 2 fathoms from it). The contents of the stomachs were:

Sclerocrangon, *Pandalus*, "crabs" (*Hyas*), Sandeels (*Ammodytes lancea*), amphipods. The average length of the cod was 1.1 m.

During the work at this station the wind and sea increased, but towards evening another station (34) was taken in the same neighbourhood on the Fyllas bank.

Sounding: 43 metres, Temperature at 40 metres 1.81° C. Handline caught in about a quarter of an hour 40 cod, 1 halibut. Fishing had to be done while keeping the ship to the wind. Wind gradually increasing to storm. Water constantly over the bow. All the night and the forenoon of August the 6th very hard squalls. Wireless aerial blown down. Leakage aft. In the afternoon wind going down, but the sea still very heavy.

Wednesday August 6th. In the morning still some rolling and some water over the bow; passed several icebergs. At 10 in the morning reached Little Halibut bank (Lille Hellefiskebank), Station 35:

Sounding: 45 metres. Temperatures: 1 metre 3.70°, 10 m. 3.34°, 25 m. 3.41°, 40 m. 2.76°. Handline 50 cod.

Fishing experiment with handline having a series of hooks at varying distances from the end (the lead):

1) First cast: 8 hooks, bait salted herrings, catch 4 cod, 1 halibut.
2) Second cast: 10 hooks: 6 cod, 4 upper hooks no catch.
3) Third cast: 10 hooks: 7 cod.

Next tried south-eastern part of Little Halibut bank (Station 36). Sounding 48 m. Temperatures: 1 m. 4.52°, 10 m. 4.10°, 25 m. 3.50°, 35 m. 2.12°.

Handline caught in a short time 15 cod, 4 halibut."

The chart, Fig. 8, illustrates the position of the "Michael Sars" stations during the period August 1st to 22nd, 1924. It also shows where fishing experiments were made and on which stations cod and halibut were found to be present. Such stations were entirely confined to the southern part, the Fyllas and Little Hellefiske bank, while fishing on the shallow parts of Great Hellefiske bank produced no positive results.

In the following table we have combined the results of the fishing with the bottom temperatures observed at the different stations.

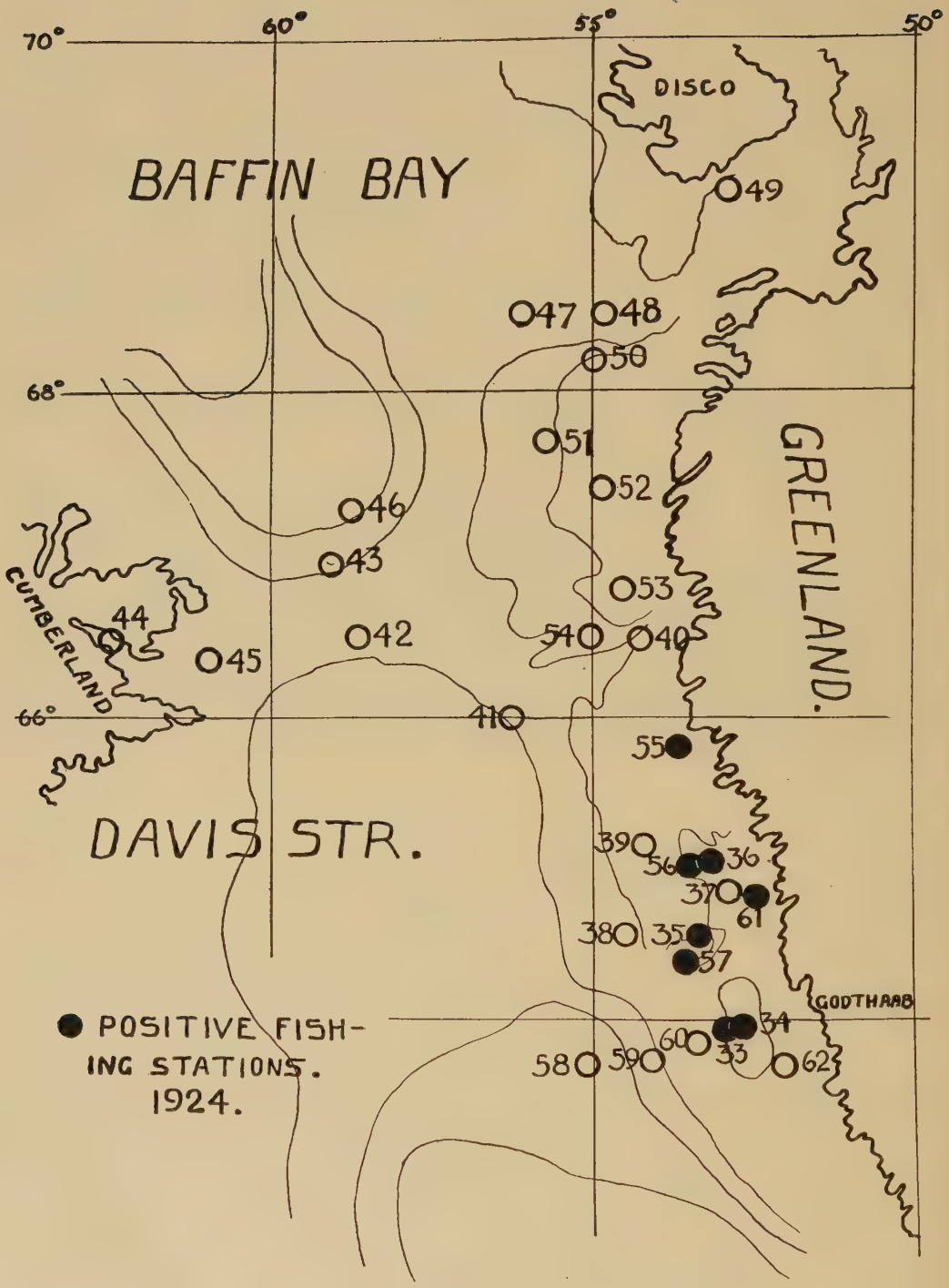

70°
60°
55°
50°
68°
66°
DISCO
BAFFIN BAY
049
047
048
050
051
052
GREENLAND.
046
043
053
CUMBERLAND
44
045
042
540
040
410
55
DAVIS STR.
390
56
36
370
61
380
35
57
GODTHAAB
34
60
33
62
580
590
● POSITIVE FISH-
ING STATIONS.
1924.

Fig. 8.

Table 2

Number of station	Sounding	Lowest depth of t. obs.	Temperature	Positive or negative result	
				Cod	Halibut
33	67 m.	60 m.	1.41°	+	+
34	42 -	40 -	1.79°	+	+
35	45 -	40 -	2.66°	+	+
36	48 -	40 -	2.01°	+	+
38	250 -	200 -	3.85°	÷	+
39	98 -	90 -	1.20°	÷	÷
50	40 -	40 -	4.13°	÷	÷
51	120 -	115 -	1.73°	÷	÷
52	40 -	35 -	4.26°	÷	÷
53	44 -	39 -	4.47°	÷	÷
55	3 miles off shore, no t. obs.			Fjord-cod	
56	44 m.	no t. observation		+	+
57	57 & 80 m.	—		+	+
61	45 m.	35 m.	2.15°	+	+

The table shows that the bottom temperatures on the southern banks where the cod and halibut were present were between 1.4° and 2.7°, while the northern bank with the higher temperature of over 4° had no cod or halibut at the time of the investigation. Experience in other waters (the Norwegian Sea) does not at all support the hypothesis that the absence of the fish is due to the somewhat higher temperature in the northern area.

Obviously, however, this question cannot be settled without much wider experience, such as that which has partly been obtained through the far more extensive fishing described in the following pages. We find that halibut were seldom found in quantities in water colder than 3° C., whereas cod has been caught in great quantities in water at a temperature of between 2° and 3° C.

On the banks the fishing was mainly done by handline, this giving just as good results as long lines, while cod-nets had proved to be impracticable because of the very strong bottom current. Only along the slope (Station 38), in deeper water (250 metres) were the long lines more practicable. Here we found, besides halibut, numbers of *Brosmius brosme*, *Anarrhicas lupus* and *A. minor*.

The contents of the stomachs of the cod contained *inter alia*, as we have seen above, Sandeels (*Ammodytes lancea*, *Norwegian siil*), a fish which plays a most important part in these waters, as the following report shows. The migrations of this fish may exercise a very great influence upon the presence of the cod and halibut on the coastal banks.

Simultaneously with the cruise of the "Michael Sars" several motorships from Aalesund were fishing on the Greenland banks; and in the succeeding years 1925—1928 many more have continued this fishing. By far the greatest interest

attaches to the extremely enterprising activities, during these years, of Mr. Engvald Baldersheim of Bergen. The expeditions which have been sent out by him, or on his initiative and under his leadership, form one of the most striking examples of what can be done to solve the extremely difficult problem of organisation involved in fishing in very distant seas, outside a coast where there are no facilities and not even access to water.

Mr. Baldersheim has been good enough to discuss this problem with Hjort from time to time and also to send him the report on the organisation and results of the expeditions made during the last five years. We publish his report here first, because it gives by far the fullest and therefore the most valuable material in existence for understanding the problem of fishing in these waters; and second, because it contains most useful material for elucidating the biology of the cod and the halibut in the North Atlantic and especially in Davis Strait.

Mr. Baldersheim's Report on Fishing in Davis Strait — 1924 to 1928.

I send you herewith a short account of the chief features of the fishing expeditions I have organized and led i Davis Strait (West Greenland) during the years 1924—1928. You are already acquainted with the main points through our previous consultations, which have been of the greatest value to me during my work in connection with these expeditions; it is therefore with much pleasure that I give you such particulars as are of interest, for your use in arranging the material from your own investigations on the banks in Davis Strait.

The first three boats sent from Norway to fish off West Greenland left in 1924. M.s. "Faustina" was despatched from Aalesund to cure cod, which according to reports previously received was present in considerable numbers on Fyllas bank. The other two boats, despatched by myself, were the m.s. "Ameta" (see Fig. 9) and the m.s. "Stormfuglen". This expedition was chiefly concerned with halibut, the plan being that the "Stormfuglen" should load fresh halibut and proceed to Fleetwood, after which m.s. "Ameta" could begin fishing for cod and proceed with a cargo of salt cod direct to Norway. This programme was carried out. The ships left in May under the command of Olav Strand, the "Stormfuglen" returning in August and the "Ameta" in September.

In the following year (1925), the glowing accounts of enormous quantities of fish in Davis Strait led to the sending out of a number of expeditions from Norway. These were all fitted out in a way which evidently did not take sufficient account of the fact that the ships had to go a distance of about 5,000 miles there and back; it was apparently forgotten, too, that no help or assistance could be got from West Greenland. Thus the ships were the same little vessels which are commonly used for expeditions to Iceland, and the supplies of bunker coal, pro-

visions, fishing gear and bait were insufficient to allow these expeditions to remain long enough on the fishing grounds to be at all remunerative; for the time during which they could work on the fishing grounds was only a fraction of the whole time occupied by the expedition. Moreover, in view of all the unknown variations and disappointments experienced on such an unfamiliar fishing ground by reason of varying weather and fishing conditions, expeditions of this kind could not possibly be profitable — a fact which was perfectly clear to me after the previous year's experiences with m.s. "Ameta" and m.s. "Stormfuglen".

Fig. 9.

Accordingly I formed a company styled "Interessentskapet Oslo", consisting of Mr. Johan Gemeiner, Captain Sverke Baldersheim and Mr. J. W. Klüwer. The resulting expedition, known as the Oslo Expedition, consisted of s.s. "Oslo", 2700 tons, as mother ship, and 16 small motor boats — which were so small that they could be placed on the deck of s.s. "Oslo" and thus transported to the fishing grounds. Only four of the fishing boats were a little too big to be put on the deck; these, therefore, were partly towed and partly navigated by their own power to the scene of the fishing. In this year halibut was again the chief object of the expeditions, so a purchased trawler was sent out as well to carry the fresh halibut to the English market. The plan was that several trawlers should be sent, with the object of dispatching a cargo of fresh halibut to England every week.

By having a mother ship of large size like the s.s. "Oslo" the expedition

could stay on the fishing grounds, and have a real season of fishing instead of a season of sailing to and fro between Norway and the fishing grounds.

As leader of this Osio Expedition I chose Bendik Mannes of Aakrehavn. But for various reasons the plans could not be carried out in their entirety, so the result was a loss.

The Expedition had a good many weak points. Among other things the fishing boats taking part in it had so much mobility of their own that they ran in close to the coast or went so far away that they could not be controlled by their leader.

Fig. 10.

The result was that the expedition was crippled, and taken into Godthaab by the Danes, losing a large part of the best time for fishing.

In these circumstances I left England in September for Davis Strait, on board a hired English trawler loaded with various necessaries, hoping to put new life into the expedition. But the expedition had returned home before I reached Davis Strait in this trawler.

Briefly, our experiences in the year 1924—1925 show: that the expedition should be based upon still larger ships, to overcome the obstacle of distance; that the organisation and administration should be more concentrated, thus enabling the person who went out in command of the expedition to have proper control of it; and that the person arranging and organizing the expedition should himself go out to the fishing grounds and assume the leadership.

In accordance with the experience thus gained, s.s. "Helder" (Fig. 10) was purchased, fitted out and equipped in 1926, and this vessel has taken part, without any changes of importance, in the expeditions of the succeeding three years (1926—1928) under my personal leadership. The expeditions in question have been financed by Messrs. I. O. and O. S. Hellyer, of Hull, who have taken much interest in the matter throughout.

The results attained with s.s. "Helder" were so satisfactory that all the fishermen made good profits on the season — in fact much better profits than other

Fig. 11.

fishermen made in a corresponding period in other fisheries. This removed one of the chief obstacles to these expeditions, namely the doubts entertained by the fishermen as to whether s.s. "Helder"s new constructions for fishing would work on the open sea and in the difficult circumstances which have sometimes to be reckoned with. These doubts had unfortunately been very considerably fostered by people supposed to be experts in fitting out expeditions, who made the mistake of expressing their opinions very freely without having the requisite knowledge of the fittings and equipment of s.s. "Helder".

Experience showed, however, that even s.s. "Helder" was not sufficiently large to satisfy the requirements from a business point of view.

In the following year, 1927, the expedition was repeated with s.s. "Helder", with the sole difference that two smaller hired motor vessels, m.s. "Skoger" and

m.s. "Lardal", were fitted out for it, as well as a hired steam-trawler named the "Imperialist". The three vessels were furnished with six motor-dories (see Fig. 11).

As experience showed that the smaller motor vessels were unpractical, s.s. "Arctic Queen", a vessel of some 10,000 tons, was purchased in the succeeding year, 1928; and from this ship fishing was carried on as successfully as from the s.s. "Helder".

The numbers engaged in the expedition of 1928 were about 500 men on board the s.s. "Arctic Queen" (see fig. 12) and about 250 men on the s.s. "Helder".

Fig. 12.

In all there were 65 motor-dories — of which about 56 took part in the fishing — on the two ships. In addition to these there was a scouting vessel, the m.s. "Antonio", and two express boats which maintained a weekly service for the delivery of fresh halibut in England.

The fitting out of this expedition to Davis Strait naturally cost several million kroner, and an amount of fish worth quite a large sum had to be caught before there could be any profit. It may be of interest, as giving an idea of the dimensions of the line-fishing on this expedition, that the length of the lines purchased and used by the expedition in 1928 would exceed the distance from Norway to West Greenland, while the aggregate length of the lines put out and used by all dories would go three times round the earth at the equator. The weight of the bait used on the lines came to about 50 tons a day, and several of the dories had a catch of more

than 100 tons of halibut for the season, while several times this weight of other fish which could not be used had to be thrown away. The best fishermen were able to earn between 3000 and 3500 kr. on the season.

The expedition worked, roughly, as follows. The fish brought to the mother ship by her dories was taken on board, put in ice, and stored, except in the case of the halibut sent to the weekly trawler for England. Between all the ships of the expedition communication was maintained by wireless, and the scouting vessel, which continually moved about to different fishing grounds, reported the results to the leader of the expedition, so that the other vessels might change over to a better place for fishing as soon as there was an opportunity.

In the years up to and including 1926 the expedition arrived on the fishing grounds about the middle of July, at which time both the cod and the halibut was to be found at a depth of 70 fathoms and in shallower water. In 1927, on the other hand, the expedition arrived on the fishing grounds about the middle of June, that is, a whole month earlier. The fish then seemed to be rather deeper down, for at first the expedition had at times to fish at a depth of about 200 fathoms, whereas the halibut afterwards kept to the shallower water as in other years. But this does not prove that all halibut rises from deep to shallower water. It is evident that halibut may be present in considerable quantities at a depth of several hundred fathoms while at the same time it is being caught right up to the surface.

In 1928 the expedition reached the fishing grounds at the beginning of June. By then the "Helder" had already been there for several weeks without finding any halibut to speak of in shallower water than 350 fathoms. On the other hand there were large quantities of cod and catfish in the deep-water slopes on Helder's bank and the southern part of Hellefiske bank, where there were likewise numbers of Sandeels. It was only when we began to fish at depths between 400 and 500 fathoms that we found halibut on the west side of the banks. Later on in June and July the fish gradually rose to shallower water, but did not, in this year, come up to really shallow water of less than 70 fathoms. This was supposed to be due to different conditions in the sea as compared with the preceding years.

The occurrence of the halibut on the banks, and its movements during the season, would seem to vary considerably from one year to another (see fig. 13). In 1924—1926 we were able to take several hundred tons of halibut on handlines, because the fish swam in shoals gorging sandeels. In 1927, and more especially in 1928, we caught hardly any halibut on handlines, although large quantities of sandeels were present in the water. We supposed the reason to be that the halibut kept at a depth below 70 fathoms.

The cod, however, was found to occur more or less uniformly on the fishing grounds in these years, both as regards quantity, and as regards the places where it appeared at different dates. There are reasons for doubting the truth of the common supposition that Fyllas bank is the most important cod bank off West

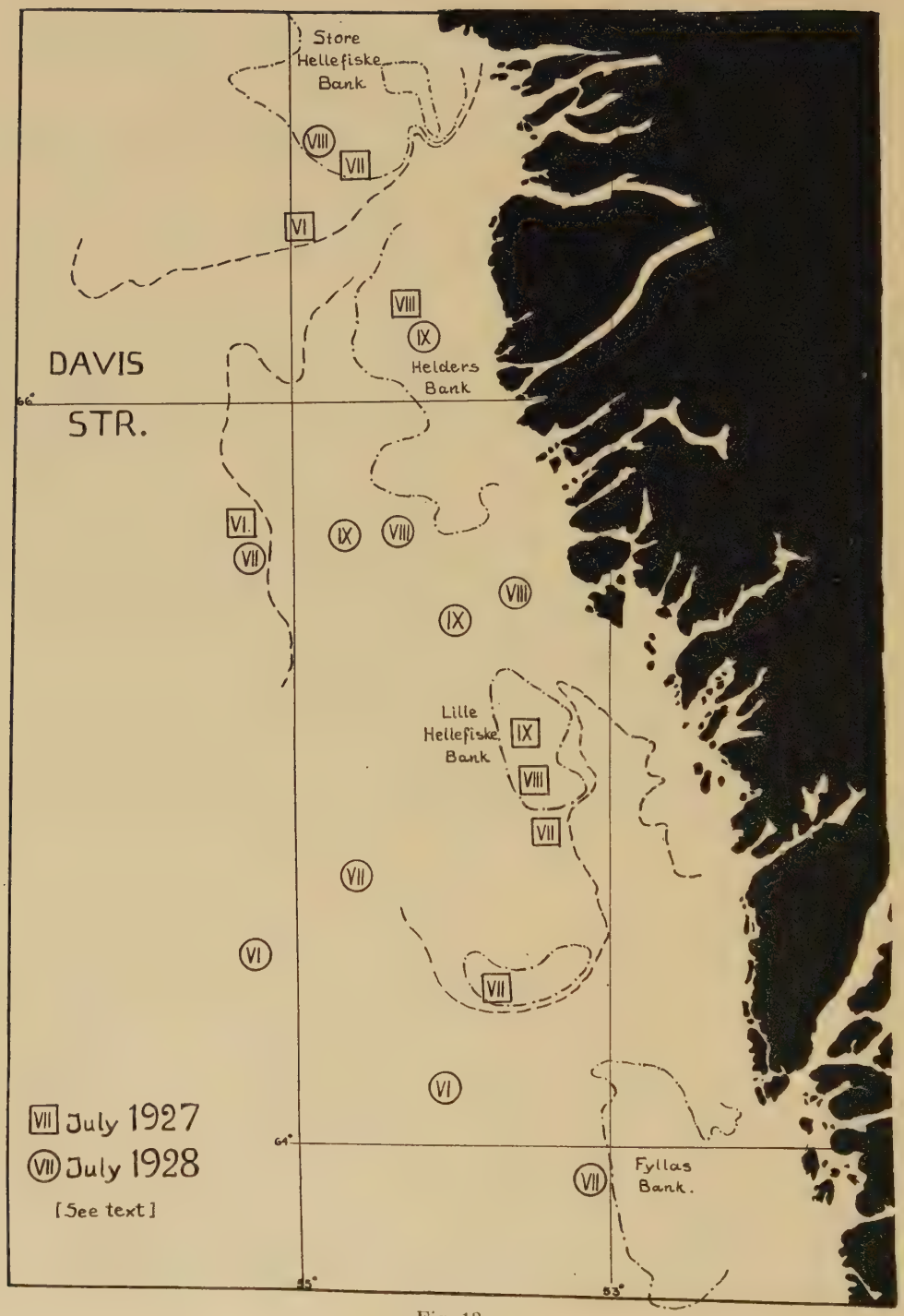

Store
Hellefiske
Bank
VIII
VII
VI
VIII
IX
Helders
Bank
DAVIS
STR.
66°
VI
VII
IX
VIII
VIII
IX
Lille
Hellefiske
Bank
IX
VIII
VII
VII
VI
VII
VI
64°
VII
Fyllas
Bank.
65°
53°
VII July 1927
VII July 1928
[See text]

Fig. 13.

Greenland, as the cod for the most part frequents it only in July and August. On the other hand the largest and most constant numbers of cod are to be found on the banks northward as far as Holstenborg, where considerable quantities were present as early as May and June on the western edge of the slope of Lille Hellefiske bank and on the edge of the slope formed by the depression between Store Hellefiske bank and the bank to the south, outside Strømfjord, which we have named Helder's bank. In these places there were often large quantities of cod when we left the fishing-grounds at the end of September. The cod on Fyllas bank has also proved to be thinner than the fish on the banks to the north.

As regards the West Greenland currents, it has long been common knowledge that an arm oi the Gulf Stream goes northwards in the deeper layer of water in Davis Strait, along the western edge of the banks where they slope towards the deep sea. This Atlantic current has an approximate force of one nautical mile an hour. When the sea rises and the massed waters of the Atlantic are driven up Davis Strait, the force of the current may increase to as much as two miles an hour (or even to three miles during a spring tide and with a south wind); when the sea subsides the force of the current decreases correspondingly, though even then the current always runs northward on the western slopes of the banks towards the deep sea.

This warm current is met, however, at Cape Farewell, by the polar current which runs southward along the east of Greenland; and this cold ocean current, probably consisting of fresher and therefore lighter water, is impelled by the warmer, salter, and therefore heavier Gulf Stream northward along the west coast of Greenland. It predominates on the southern banks in the Julianehaab district, while farther to the north, especially from Fyllas bank onwards, it loses ground before the powerful influence of the above-mentioned arm of the Gulf Stream, which here advances over the shallower part of the banks — as is especially noticeable on Helder's bank and the southern part of Store Hellefiske bank. Judging from the temperature readings I am inclined to think that the water of the Gulf Stream would be strong enough in autumn to flow over the banks near Julianehaab and fill the fjords there with water from the Atlantic.

The third feature of the currents is the cold water which comes from the great group of fjords on the west of Greenland and may properly be regarded as an addition to the cold polar current which bends northwards past Cape Farewell.

The vast agglomeration of fjords in West Greenland, and the formation of the banks, result near the coast in certain disturbances of the main north-going currents. Thus in places, e. g. off Godthaab and Strømfjorden, there are apparently alternating west and east going currents, according to the tide; though these are only in evidence at a certain distance from land, according to the tide and the formation of the banks, which have hitherto only been indicated tentatively on the available charts.

The temperature of the sea is apparently governed by the above-mentioned currents. The scouting vessel which continually sailed up and down the banks carrying on experimental fishing and taking the temperature of the sea both at the surface and at the bottom, wherever she went, was able to obtain a picture of the temperature conditions which may be summarized thus:

At the beginning of June: Fyllas bank $^1/_2$° C. at bottom and surface. Lille Hellefiske bank $^1/_2$°C. at bottom and surface. Helder's bank $^1/_2$—1° at surface, 2° at bottom. Southern edge of Store Hellefiske bank 2° at surface and 3° at bottom.

At the end of June: Fyllas bank $^1/_2$° at surface, 2° at bottom. Lille Hellefiske bank 2° at surface, $2^1/_2$° at bottom. Helder's bank 2° at surface, 3° at bottom. Southern edge of Store Hellefiske bank $2^1/_2$° at surface and 3—$3^1/_2$° at bottom.

At the end of July: Fyllas bank at surface $2^1/_2$°, at bottom 3°. Lille Hellefiske bank surface and bottom 3°—$3^1/_2$°. Helder's bank $3^1/_2$° at bottom and surface. Southern edge of Store Hellefiske bank $3^1/_2$°—4° both at bottom and surface.

In August the temperature keeps about the same as at the end of July. The halibut seems to avoid water below the temperature of + 3° C.

At the end of August and September the temperature begins to fall again.

These temperatures are mean readings, so they are liable to vary in different years.

As the warm water makes its way in summer across the banks towards the coast, the fish likewise draw closer in, but it is impossible to say with any certainty whether the fish migrate from the deep sea towards the coast or whether they simultaneously move northward during the first part of the summer. Nor do we know whether the fish enter the fjords in any numbers. Further, we cannot tell at all whether or not the fish disappear from the banks in Davis Strait in winter. Certainly they disappear from the shallower parts of the banks, but personally I am of the opinion that there are fish all the year round on the western edge of the banks; and I believe that e. g. the halibut caught off Holstenborg does not go far south, but rather westward to the deeper layers of water, which are sufficiently warm for it to pass the winter there, as do most of the living creatures of the sea (other fish and crustacea).

There is reason to believe that conditions similar to those mentioned with regard to these banks apply also to the banks lying farther south, right down to Cape Farewell, except for the difference that the cold polar current is more predominant (and sinks farther down) as one proceeds southward.

The fish we caught with lines included halibut (halibut and Greenland halibut), cod, skate, tusk, catfish, (mottled and blue), Norway Haddock and Greenland shark. The contents of the stomachs indicate the presence of very considerable quantities of dab, prawns, various species of crabs, small cuttlefish, *Ammodytes* and *Mallotus*, besides many different species of shell-fish.

In connection with the information given by Mr. BALDERSHEIM we may add that we have ascertained that the catches in these years were as follows:

In 1926 24 motor-dories were used. During the fishing they always tried to keep away from the places where cod was found to be present, as the intention was to catch halibut. The amount of halibut caught was 1300 tons. The quantity of cod cured (split and salted) was 300 tons. It is probable that the cod cured would have amounted to 1300 tons several times over, if the boats had been fishing for cod.

In 1927 the 40 dories used caught 3000 tons of halibut. Moreover very many tons were thrown away daily because the fish was too coarse or otherwise unsuitable. No cod was caught, though this fish was present in as large quantities as in 1926.

In 1928 there were about 60 dories, and about 56 of these were used for the fishing. The catch amounted to about 4000 tons of halibut, and about 300 tons were thrown away. Every effort was made to avoid taking cod, but a great deal had to be thrown away all the same. About 800—900 tons of salt cod were taken home from the fishing grounds.

In the first and second years the halibut kept very much to the top of the banks, but in the last year it was chiefly found on the slopes at depths ranging from 80 to 100 fathoms. The average weight of the halibut caught during these years was 18—20 kg.; perhaps a little less in the last year.

B. Whales and the Plankton.

Modern whaling, founded on the catching of finbacks, is a comparatively new industry in Davis Strait. Some small expeditions were sent out from Sandefjord, in Norway, just before the war, and again immediately after the war, in the years 1919—1925.

For the expedition of the "Michael Sars" in 1924 it was of vital importance that the Tønsberg Hvalfangeri decided in that year to send their floating factory, the s.s. "Orwell", with 3 small whalers, the s.s. "Husvik", s.s. "Ruggen" and s.s. "Sperm" to Davis Strait. The extremely liberal and friendly assistance afforded by this expedition to the s.s. "Michael Sars" in the form of coal and many other most necessary supplies, was very valuable and acceptable. But of no less importance was the advice and information concerning the whereabouts of the whales and the exact places where they had been caught, which we received from the leader of the expedition, Captain SØREN BERNTSEN.

The two expeditions met "by appointment" on the 8th of August near our Station 40 (see Figure 8). It was then decided that the two expeditions should cross Davis Strait to Cumberland and enter the great fjord known as Exeter Sound, partly for the purpose of getting fresh water from one of the icebergs there, and partly to investigate the facilities offered by the other side of the Strait for expedi-

tions in that area. While the whalers were busy whaling, the "Michael Sars" completed the section with stations 40—44, and by the evening of the 9th of August the five ships were at anchor in Exeter Sound.

The conditions on this crossing of the Strait were very favourable for our purpose. The belt of ice outside the fjord only consisted of scattered pieces of ice of different sizes. In the fjord we found some large flat-topped icebergs, having small "lakes" of fresh water, from which the water needed by both expeditions was taken. While the "Michael Sars" was coaling Captain BERNTSEN gave us the following information about the result of his whaling in the Strait.

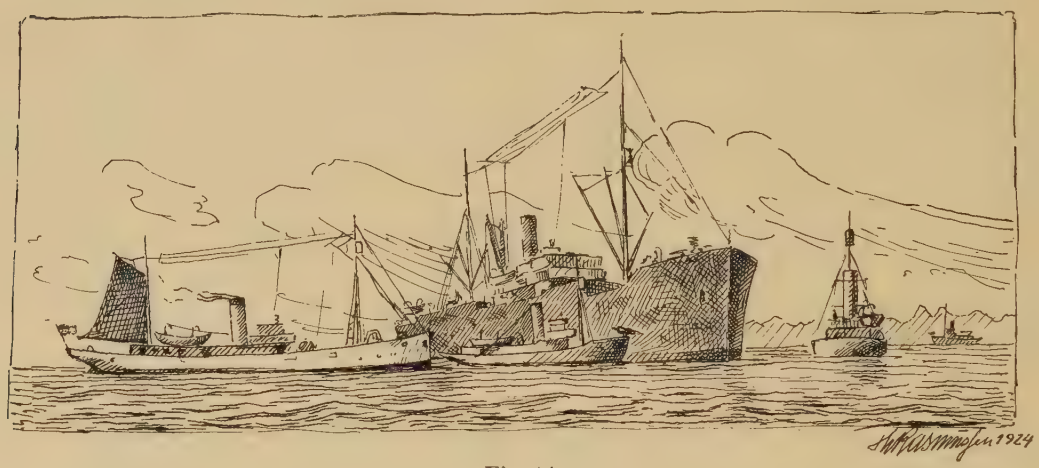


Fig. 14.

The whaling started in the Strait on the 10th of July, and between that date and the 8th of August the three whalers caught 80 whales, of which 34 were blue-whales, 24 fin-backs, 18 hump-backs, 2 sei-whales and 2 sperm-whales.

The places where these whales were caught are marked on the chart, Fig. 19. It is very important that the sei-whales and hump-backs were caught well in upon the banks, the sperm-whales well outside the banks and all the blue and fin-back whales along the slopes of the coastal banks.

The oil obtained from these 80 whales amounted to 2500 barrels, which would give an average of 31 barrels a whale; but the Captain considered that the average should be

10—15 barrels from a fin-back
40—50 — — - blue-whale
20—25 — — - hump-back.

This result was considered a great disappointment. Both the small number of whales and the quality of the whales caught were far below what was expected,

and the results of previous expeditions. The blubber (along the side) of the finbacks was of the insignificant thickness of 1—1 1/2 inches.

Very little "krill" had been observed during the whaling operations and this was mainly in the Bay of Disco (see Stations 48 and 49). The whalers considered the summer of 1924 most unfavourable, and thought that there might be a greater number of whales and greater quantities of whale's food in other years.

For the "Michael Sars" expedition this information was of great value as a guide in planning the rest of the cruise in Davis Strait. Obviously an investigation

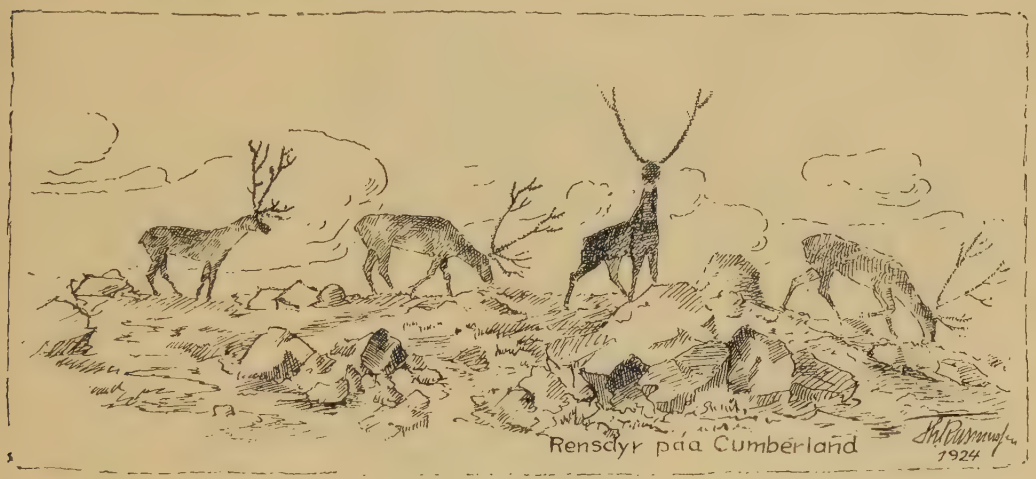


Fig. 15.

along the grounds where whaling had already taken place would be very interesting, but a comparison with the parts of the Strait where no whales had been observed would be of equal interest.

A comparison of the chart Fig. 19, and the two hydrographical sections, Figs. 3 and 4, will at once convince the reader, that no whales had been caught in the area of the very cold water of the south-going westerly current.

The stations in these sections, nos. 40—45, in conjunction with another section from Exeter Sound to Disco Bay (Stations 45—49), and above all a closer examination of the animal life in Exeter Sound itself, would enable us to become acquainted with the biology and conditions of life in the true arctic parts of the Strait.

The first sight from the deck of the "Michael Sars" on the morning of Sunday August 10th was a herd of "reindeer", forming a beautiful silhouette against the clear sky.

On shore we met a number of quite peaceable polar bears walking about in the hills.

Making an excursion in the afternoon all round the vast fjord we observed a great number of walruses, some of them digging at the bottom of shallow bays, others resting on large floating pieces of ice. More than 50 of these arctic animals were observed on the excursion.

Of great interest was Station 44, which we were able to take some days later after we had finished coaling and taking in supplies of water from the iceberg.

Fig. 16.

Table 3. "Michael Sars", Station 44. August 13th 1924. 66°27′ N. 62°35′ W. Depth 270 m.

Depth metres	T°	S ‰	σ_t	O_2 cc	M ‰	P_H
1.....	2.29	20.05	15.58	8.33	—	8.14
10.....	1.10	30.03	24.07	85	110	13
25.....	÷ 1.72	31.44	25.31	85	107	15
50.....	÷ 25	32.52	26.17	29	98	14
75.....	÷ 40	75	37	7.64	90	10
100.....	÷ 53	92	50	70	91	7.90
200.....	÷ 74	33.19	73	29	86	90
250.....	÷ 68	19	73	62	90	88

The hydrographic observations are of great value for understanding pelagic life in these arctic conditions and are therefore repeated here.

Fig. 17.

Fig. 18.

We find a very cold layer, with a temperature below freezing point, from 25 m. down to the bottom. From the contents of the oxygen and hydrogenion concentration of the upper layer we may conclude that there is a rich accumulation

of plants in the surface water. GRAN confirms this assumption in his remarks on this station (GRAN, in this volume).

"Harsh as this coast appears, with its ice-worn beaches, bearing never a sign of Fucaceae, only here and there a laminaria with long air-filled stalks reaching to the surface, it is not surprising that even up in the fjords the oceanic species should predominate; it is rather to be wondered at that the land can send down any sufficient supply of nourishment to maintain a fairly rich production. For it is extremely likely that it is the supply of nourishment from land which enables the diatoms to flourish not only up in the bay but even as far out as Station 45; in the middle of Davis Strait (St. 42, 43 and 46) the diatoms are altogether far more rare."

A comparatively large volume of animal plankton corresponding to the development of vegetable plankton, was also characteristic of this station in the fjord. (See STØRMER, page 45 in this volume.) Of the larger animal plankton the Amphipoda were very numerous, especially the species *Themisto libellula* and *Parathemisto oblivia*. Schizopods were represented by three species: *Thysanoessa inermis* (et *neglecta*) and *Mysis oculata*. Among Pteropods *Limacina arctica* was represented by many individuals and *Clione limacina* by one specimen in a deep haul.

Station 44 may be considered as the western extremity of two sections of Davis Strait, taken from Cumberland to the Greenland coast. The southern section, following a course due east, comprises stations 44, 45, 42, 41 and 40; the northern section, running in a north-easterly direction towards the Bay of Disco, comprises stations 44, 45, 46, 47, 48 and 49.

With reference to the question of the distribution of Schizopods, Amphipods and some other important species, we may make the following general remarks on the distribution of these animals in the two sections:

1) If, first, we consider the distribution of the earliest stages of the species of Thysanoessa as found in vertical hauls in the upper layer, between 50 metres and the surface, we may construct the table 4, with the stations arranged from west to east.

Table 4.

Stations	Southern Section				Northern Section				
	44	42	41	40	45	46	47	48	49
Eggs	..	..	..	24	..	..	..	200	18
Nauplii	..	..	..	35	..	..	1	220	3
Metanauplii	..	..	..	15	..	..	..	40	..
Calyptopis	..	..	40	11	..	..	1	40	15
Furcilia	..	9	5	..	..	..	8	60	6
Cyrtopia	..	..	..	..	..	..	3	20	..

We see from this table that the earliest stages — the eggs and nauplii — are entirely confined to the stations by or on the slope of the coastal banks (Stations 41, 40 and 48 and 49). The spawning place of these species would thus appear to be restricted to the eastern side of the area, while older stages may drift northward, and finally also westward as the individuals develop.

2) As regards the adults of the different species of Schizopods we may mention that the

Meganyctiphanes norvegica was only found in two cases, at the two easterly Stations 40 and 41; at the latter station 6 specimens were taken in a deep haul (600 m. wire). Similarly

Thysanoessa raschi was only found at the three easterly Stations 40, 48 and 49 (great numbers in tow-nets)

Thysanoessa longicaudata appeared at the central Stations 41, 42, 43,

Thysanoessa inermis was found both at the western and the eastern stations.

Mysis oculata was confined to the arctic Station 44.

3) Among the Amphipods the two dominant species, *Parathemisto oblivia* and *Themisto libellula*, were found on all stations, but with a marked increase in numbers towards the western side of the Strait. *Themisto compressa* and *T. bispinosa* seem to favour the eastern side.

Besides these two sections of the Strait our material provides us with interesting data for the study of the distribution of the different species on the banks (Stations 32, 33, 35, 37, 38, 39 and 54) and in the waters outside the banks to the south of the Fyllas bank (Stations 58, 59, 60 and 62).

At all the stations taken in water over the banks we find the following forms:

Early stages of *Thysanoessa* sp.

Meganyctiphanes norvegica.

The two amphipods *Themisto bispinosa* and *T. compressa.*

The section over Fyllas bank has the same characteristic distribution of the young of the genus *Thysanoessa*; all the earliest stages were found on the innermost station on the bank. On the outer station (58) no fewer than 22 *Meganyctiphanes norvegica* were taken in a deep haul (1000 m. wire) and on Stations 58 and 59 *Thysanoessa longicaudata* was present. The Amphipods were represented by the two above-mentioned species *Themisto compressa* and *T. bispinosa.*

On Figure 19 the occurrence of the whales is correlated with the distribution of the early stages of the Schizopods. These early stages afford the best, perhaps the only means of determining the quantitative distribution of these creatures, as they can then be taken in vertical hauls; whereas the full-grown specimens are much more difficult to catch, and have therefore to be taken by horizontal towing with larger nets for a long distance.

The figure illustrates very well the correlation between the distribution of the young Schizopods, or "krill" as the whalers call them, and the presence of

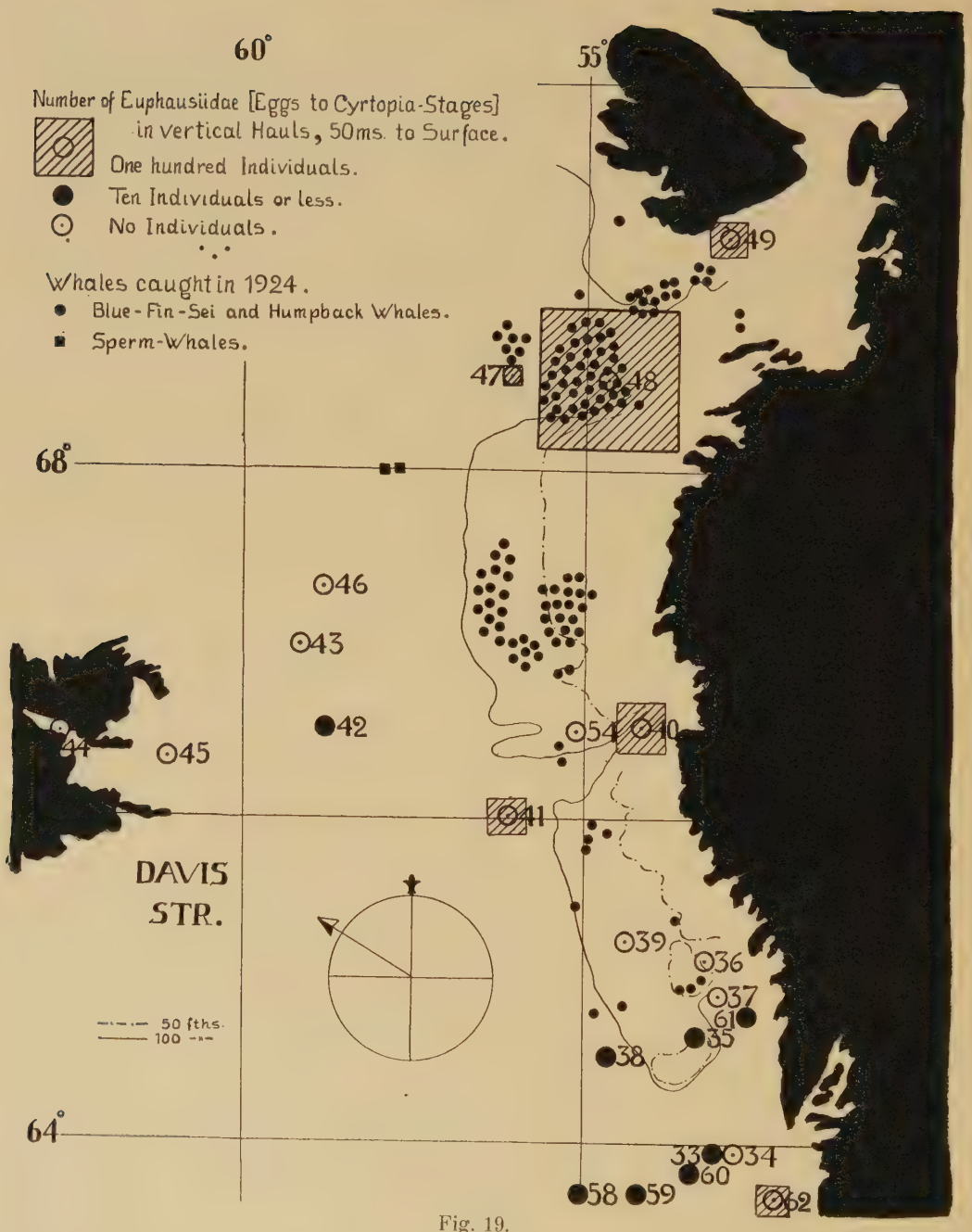


Fig. 19.

whales. By far the most prolific place was the entrance to the Bay of Disco. The richest hauls were made at Station 48, where numbers of *Thysanoessa raschi* were

taken. At this station a large tow-net also caught shrimps, e. g. the Pasiphae and Pandalus. As we have seen, the whalers had previously described this station as the richest place for whale-food and whales.

On the voyage from Iceland to Davis Strait, and similarly on the return voyage, the "Michael Sars" completed a few stations in deep Atlantic water. These stations, nos. 27, 28, 29 and 66, are interesting as helping to throw light on the distribution of the species we are considering here; they show that the following species were present:

Among the Schizopods: *Thysanoessa longicaudata* and *Eucopia unguiculata.*

Among the Amphipods: *Themisto compressa* and *T. bispinosa.*

These species were, as we have seen, especially in evidence along the slope of the eastern coastal banks in Davis Strait.

In another respect, too, the distribution of these Schizopods is of great interest. On all the Atlantic stations just mentioned the two species were confined to the deeper layers, below 800 metres. This appears to agree with the very characteristic distribution of a number of other boreal species, which were found during the cruise of the "Michael Sars" in 1910, in the upper layers on the New Foundland bank and in the deep layers in a cross-section from New-Foundland to Scotland. See e. g. Fig. 51 taken from the "Depths of the Ocean" and illustrating the vertical distribution of the pteropod *Clione limacina* along the section. *Clione limacina* was also found in Davis Strait in 1924, on the coast-bank Stations 31, 32, 40, 41, 48 and 49 and all along the southern section, Stations 58—62, everywhere in the upper layers at small depths.

At all these stations, therefore, the species was found in comparatively warm water — a mixture of Atlantic and cold coast-water current; and it may be added that young specimens were found nowhere else. At three stations, 42—44, just a few large specimens were caught in cold, genuinely polar water.

Chapter II.

The Norwegian Sea.

A. Fisheries along the Slope of the Continental Shelf.

Historical Remarks.

Fishing on the high seas, far away from land, has in all countries developed from local fisheries along the coast; but its history in different countries has varied greatly; the development depending, among many other special circumstances,

upon the topography, i.e. the depths of the sea bottom outside coastal waters. In the countries bordering upon the southern part of the North Sea, where plentiful supplies of valuable food fishes could be caught in large shallow areas not very much deeper than the sandy beaches of the coast, the progress of a sea-going fishery was continuous and closely connected with the invention and improvement of the trawl. In two of the Scandinavian countries, Norway and Sweden, the bottom of the sea drops away very steeply from the coast, the hundred fathom line being very near to the coast. The steep slope from the coast has a very rough bottom, at most places quite unsuitable for trawling.

In the area of the North Sea and Skager Rak — all the sea south of 61° N. — the coast is bordered by a deep and broad channel, known as the Norwegian Channel, where the sea bottom has deep layers of mud, in which the animal life is too scanty to form a fishing-ground. North of 61° N. there are, it is true, smaller coast-banks outside certain parts of the coast, where fishing has been found profitable during certain months of the year; but these banks are everywhere too small to serve as a basis for a real and extensive industry. The development of a sea-going fishery from the Scandinavian countries was, therefore, retarded; and for a long period of years it was far behind the prosperous, advance of the fishing industries of the other North Sea countries. As late as the 'fifties the Scandinavian industry had markedly the character of a coast fishery using open or very small decked boats, which were unable to cross the deep channel and start fishing on the North Sea bank.

About the middle of last century the fishermen both along the Bohuslæn coast of Sweden and along the coast of Möre in Norway simultaneously began to try their long lines on the slope of the coastal banks and of the great North Sea bank. This bank shelves rather steeply down to the Channel. The "edge" and "slope" of the bank are called by Scandinavian fishermen revet or the "reef" of the North Sea.

The fishermen found here a peculiar and very large community of fish, mainly consisting of cod, ling (*Molva molva*), blue ling or bjørklange (*Molva byrkelange*), tusk (*Brosmius brosme*) and halibut. The "roundfish" were salted in bins, the halibut used as food for the crew, and these fishing voyages some times lasted for several weeks.

The development of this industry was rather slow, as the fishermen did not earn much more than a bare living. Gradually the Swedish fishermen extended their voyages further away from their own coast. In the 'fifties they reached the slope to the south west of Norway, and in the 'sixties they went as far as Möre, where they met the Norwegian fishermen, who for some time had carried on a fishery of the same kind all round the entrance of the Norwegian Channel into the deep Norwegian Sea.

During the last decades of last century the further development did not

consist so much in an extension of the field of operations as in a very great improvement of the fishing fleet. Larger sailing smacks and even small steamers were used for this kind of fishing, which gradually assumed the feature of a regular seasonal part of the fishermen's annual plan of operations. For details of this development see HJORT (1905).

At the beginning of the present century, when the Norwegian research steamer "Michael Sars" was procured, a systematic investigation was planned of all the banks, edges and slopes of the North Atlantic at the entrance to the Norwegian Sea, as well as the continental shelf and the slopes of the Norwegian Sea itself.

Thousands of square miles had then never been subjected to fishing operations, and to cover this enormous area within a reasonable time fishing steamers were chartered to work under special control in places where the research steamer had found indications of a good fishing ground or had good reasons to expect one. Besides this, advantage was taken of all opportunities to get precise information from the fishing fleet.

All the information obtained in accordance with this plan was published in a book, with charts of the areas investigated, giving the localities of the stations where fishing had taken place, and with lists of the species caught at each station (HJORT 1905).

Fig. 20.

The material obtained by the thousands of fishing experiments mentioned in this publication has an important and direct bearing on the problems which will be discussed in the following chapter. We will therefore proceed to review as briefly as possible the points which appear to be of special interest in relation to these problems.

Fishing Experiments.

The chart, Fig. 21, serves as a general indication of the topography (or depths) of the Norwegian Sea and the neighbouring waters of the North Atlantic,

the North Sea and the Barents Sea. Roman numbers indicate the positions of the different areas in which characteristic experiments were carried out. The space available and the plan of this paper only allow us to give the main results of the fishing experiments in a very concise summary.

(I) The Iceland-Faroe ridge. The broad ridge or bank connecting the two plateaux around Iceland and the Faroe Islands has, everywhere, a depth of about 500 metres or 200—300 fathoms. In August 1902 the "Michael Sars" had 9 fishing stations on these banks in depths between 185 and 260 fathoms. At all the stations only quite short lines were used, with a total of 3120 hooks for all stations. 365 fish were caught: 83 large halibut, 2 black halibut, 48 cod, 139 tusk, 61 blue ling, 10 catfish (*Anarrhicas*), 6 Sebastes, 5 Greenland sharks, 11 Rays of different species. The large number of large halibut and of blue ling is very interesting. Of interest, also, is the fact that the stomachs of a great many of the fishes contained *Ommatostrephes todarus* — the squid being with *Gonatus fabricii* and the herring the main food of the bottle-nose.

(II) During the same summer a great many experiments had been made on the northern and eastern slopes of the Faroe bank, where very similar catches had been obtained.

In June 1902 the first experiment produced very promising results. At depths of from 224 to 250 fathoms 800 hooks caught 10 large halibut, 10 cod, 65 tusk, 7 blue ling.

At the beginning of July, therefore, the experiments were continued on a larger scale and 5000 kilos of halibut were taken in a few days. As an example it may be mentioned that: 24 large halibut, 25 cod, 117 tusk, 6 blue ling and 7 ling were caught on 800 hooks.

Another still larger experiment with 8850 hooks secured:—

149 large halibut weighing 7000 kilos,
445 cod,
784 tusk,
105 blue ling and a few other fish.

The news of these results brought 24 steamers to the same ground during the following weeks, and according to the local press the following catch was made:

346,200 kilos of halibut,
24,077 cod,
46,197 tusk,
1,007 ling,
1,644 blue ling.

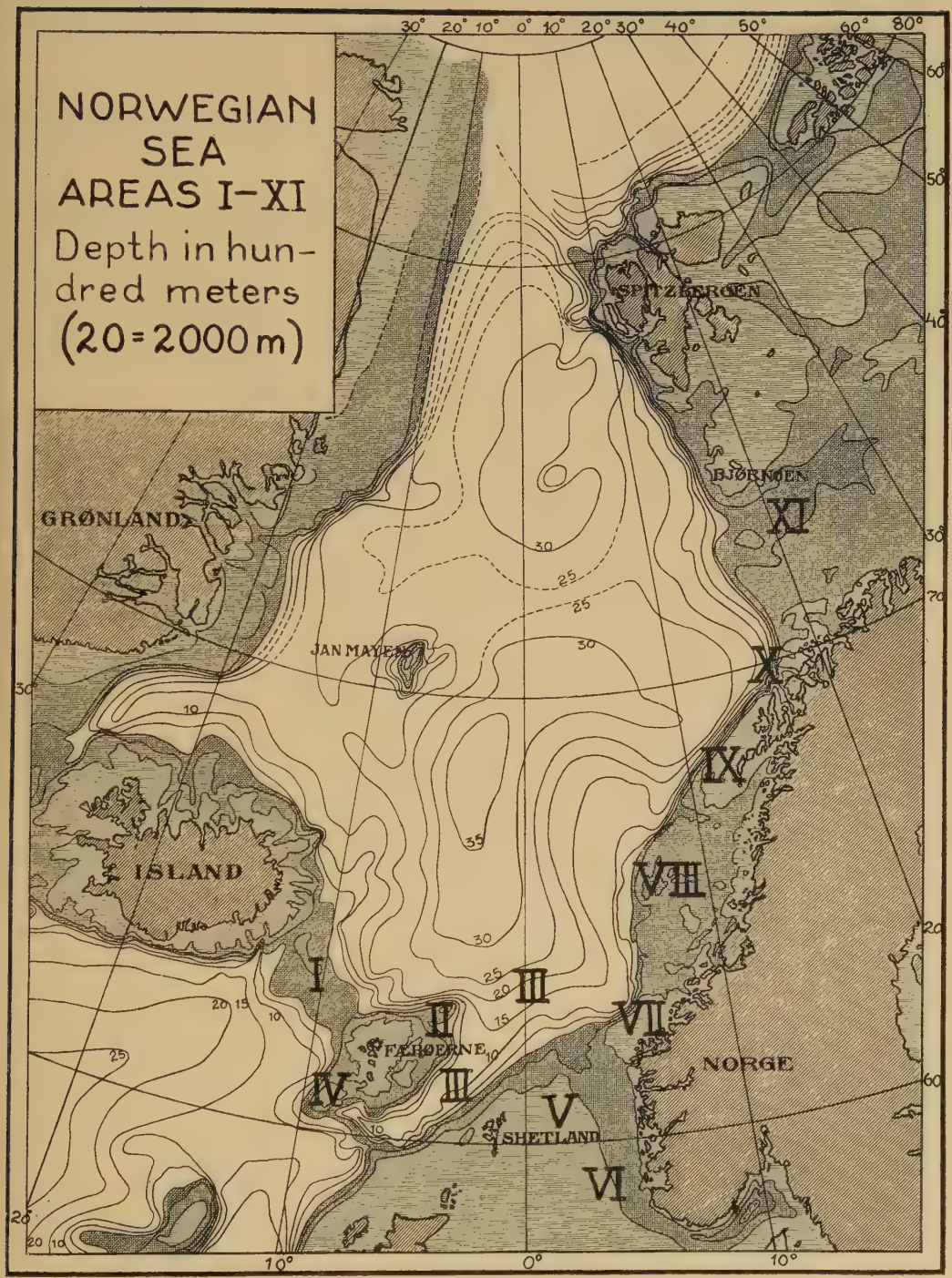

NORWEGIAN
SEA
AREAS I–XI
Depth in hun-
dred meters
(20=2000 m)
GRØNLAND
ISLAND
JAN MAYEN
SPITZBERGEN
BJØRNØEN
FÆRØERNE
SHETLAND
NORGE
I
II
III
IV
V
VI
VII
VIII
IX
X
XI

Fig. 21.

Of great importance are the repeated observations made to the effect that the stomachs of cod and halibut were found to contain herrings, as well as the squid mentioned above.

(III) The experiments carried on along the north-eastern slope of the Faroe bank proved that a community of valuable food fishes existed there, and that this could serve as the basis of an important fishery at least down to nearly 300 fathoms or over 500 metres.

A series of experiments have proved that in deeper waters a sudden change takes place — a quite different fauna of fish and lower animal life taking the place of these boreal forms. As will be seen from the chart, we have stations below the 300 fathom line and even down to more than 700 fathoms. These stations are partly to be found in the so-called Faroe-Shetland channel and partly north of the slope of the North Sea towards the great deep of the Norwegian Sea.

While the temperatures were found to vary between 3° and 7° C. on the Iceland-Faroe ridge and between 5° and 6° C. on the north-eastern slope of the Faroe bank, at about 400—500 metres, they were all below freezing point in the deeper layers.

The most important fish caught in this cold area are the following:—

Lycodes muraena, *flagellicanda*, *frigidus*, *pallidus*, *similis*, *eudipleurostictus*, *seminudus*.

Careproctus Reinhardti, *Paraliparis bathybii*.

Rhodichthys regina, *Cottunculus microps* and *sub-spinosus*, and finally

Raja hyperboreus and the Greenland shark.

This community of fishes is confined to the cold deep sea plain and may be found all over this area, right up to Spitzbergen and perhaps still further north.

(IV) An equally interesting task was, of course, the investigation of the distribution of the food fishes of the Faroe bank along the greater depths of the North Atlantic slope. A series of trawlings have shown that a boundary must be drawn at about 400 fathoms, although the temperatures here are high; in 1000 metres the temperature was found to be 7.9° C.

Along the southern slope of the Faroe bank, at depths between 200 and 300 fathoms, the first representatives of a new community, the Centrophoridae, begin to appear among the boreal fishes. And between 400 and 700 fathoms the community of fishes belonging to the northern Atlantic slopes are entirely dominant. We have here 4 species of the genus *Centrophorus* (*C. calceus*, *squamosus*, *crepidater* and *coelolepis*) a new species of *Chimaera* (*C. mirabilis*), a new *Spinax* (*Etmopterus princeps*) and *Centroscyllium fabricii*. Among other species may be mentioned: *Notacanthus bonapartei*, *Haloporphyrus eques* and *H. affinis*, *Trachyrhynchus murrayi* and several Coryphaenoids.

(V) The northern slope of the North Sea, which the Norwegian fishermen call "Tampen" or the tail of the bank, has for many years been a fishing ground

for fishermen of many nationalities; it need not, therefore, be described in any detail here.

In a great number of experiments we found, at depths ranging from 150 to 250 fathoms, the usual species belonging to the boreal part of the slope: halibut, ling, blue ling, cod, tusk, large haddock, rays of different species (*Raja batis*, *vomer*, *fullonica*, *circularis*), *Pristiurus melanostomus*. The halibut was often of small size (86—108 cm.). *Accanthias vulgaris* and *Spinax niger* were also present.

(VI) The Norwegian Channel has perhaps been more thoroughly investigated than any other area. Here the Swedish fishermen have for nearly a hundred years fished on every part of the ground where a long line can be hauled. Here the fishermen have their own special names for each part descriptive of the characteristics of the sea bottom in the different localities. Particulars of all this will be found in the book from which these details are taken (Hjort 1905). From the information supplied by Swedish fishermen and quoted there, it will be seen that the catch all along the slope of the North Sea is composed of the same species. Quantitatively, however, the composition of the catch seems to differ from the catches made on the Faroe bank. The ling proper (*Molva molva*) plays by far the most important part here; it is much more abundant than the cod, while the tusk is quite insignificant. Blue ling seems to be absent. The halibut are rather small in size in this area: 55, 72, 78, 104, 64—110, 58—109 cm. are lengths given in the journal of the "Michael Sars" regarding the experiments carried out all along this slope.

(VII) The slope of the Möre bank or Romsdal bank has also for a long period been a most important fishing ground. Like the slope of the North sea bank the slope of the Möre bank has a long series of special localities named by the fishermen, who locate them by means of cross bearings on the high mountains of the coast. The species of fish are here precisely the same as on the northern slope of the North Sea.

Long experience has taught the fishermen that there are regular times for the appearance of the different species. In the spring and summer the fishing is based on the ling. From 70 to 80 ling may be caught on a line with 900 hooks. 50 ling per line just pay the expenses of the voyage. From the month of September onwards the halibut makes its appearance, and subsequently it is caught all through the autumn, especially on the western part of the slope towards the entrance to the Norwegian Channel. The halibut assemble here towards the month of November, when this fish is said to spawn. At Christmas time it is said to be of no value, being spent and thin. The best depth for halibut fishing is said to be from 250 to 300 fathoms. Large fish seldom go to smaller depths. The large halibut attain a weight of some 150 kilos. Cases are known of 2000 kilos being caught on a long line with 900 hooks.

The ling is said to go no deeper than 280 fathoms, but may be caught in great numbers down to 250 fathoms. Farther down than 300 fathoms the catch

is limited to the blue ling (*Molva byrkelange*), the black-halibut, *Macrurus fabricii*, *Chimaera monstrosa* and *Argentina silus*. See Figure 2, the hydrographical section of the Norwegian Sea.

(VIII) North of the Romsdal bank the slope bends away from the coast-line. The distance from the coast to the slope is therefore still greater and the coast banks are deep and not very rich in fish. The slope off the coast of Helgeland was, therefore, quite unknown to the fishermen before the fishing experiments carried out between June and September 1903.

We shall confine ourselves to a short summary of the more interesting features of this undertaking.

On about 100,000 hooks a catch of 31,509 fish was made. It comprised:—

713	(large) halibut
537	cod
4,085	ling
494	blue ling
25,680	tusk.

The halibut was stated to be mostly between 30 and 50 kilos in weight.

The fishing took place all along a ridge parallel to the coast, mostly in depths ranging from 150 to 300 fathoms.

The blue ling were all caught at a depth of between 250 and 300 fathoms.

The result of these experiments was considered very favourable, and a great many fishing steamers have worked on this fishing ground ever since.

(IX) This is the district, where the great Lofoten fishing takes place on the coastal bank inside the Lofoten Islands, in what is known as West Fjord. Although cod fishing has taken place in this area for almost a thousand years, fishing on the slope of the Continental Shelf used to be almost entirely restricted to one place, where the slope approaches to within a few miles from the coast (off Andenes).

A great number of fishing experiments were made in the years 1899 to 1903 and the results are given among the records of the other experiments. The fishing along this slope proved to be very difficult, because the formation of the bottom was found to be very irregular and much time had to be devoted to extensive soundings before fishing could start. Besides this, the north easterly current was very strong; it has repeatedly been reported as "running like a river". These difficulties are, however, also present elsewhere, e.g. off the coast of Möre, but have here been overcome through long experience gained in many years of hard work. In spite of all this a great number of cases are recorded of successful fishing; for instance a fishing steamer has been able to catch, in the course of a week, about 3000 kilos of halibut, 3000 kilos of ling, 2000 kilos of cod and 2000 kilos of tusk.

(X) The district of Tromsö is most interesting, because there is a series of quite small banks, having a depth below 50 fathoms, very near the steepest part of the whole slope. A great number of fishing experiments were carried out in this area during the summer of 1903.

On 37,800 hooks, hauled on the banks at depths of less than 100 fathoms, the following fish were caught:—

2,003 halibut	52 haddock
626 cod	61 saithe
2,350 tusk	91 catfish
233 ling	7 Greenland shark

The halibut were all small, in one case 2—8 kilos, in other cases 5, 7 and 10 kilos.

Hauls (9,000 hooks) from depths of 150—250 fathoms caught 115 large halibut, 187 cod, 78 ling, 3 blue-ling, 1,793 tusk, 25 haddock, 5 Greenland shark.

At 300 fathoms there was no halibut.

(XI) Since the British trawlers discovered the large stock of plaice on the coastal banks off the Murman coast and Cape Kanin a great development has taken place in the fisheries of the Barents Sea. Topographically this sea may be described as a broad valley or several parallel valleys, where the depths may be some 150 fathoms over large areas. From these valleys the sea bottom slopes upwards towards the Norwegian and Murman coastal banks in the South and towards the Bear Island bank in the north.

A great number of fishing experiments have been carried on in this large sea. Hauls of long lines and trawls have been tried at different seasons and in different parts. For purposes of comparison with the other areas mentioned above we need only mention some experiments with long lines made in the summer of 1903 in a zone about 100 miles broad, parallel to the Norwegian coast. During these experiments some 500,000 hooks were hauled in with a total catch of 130,000 kilos of different species of fish: 3,000 kilos of halibut, 95,000 kilos of cod, 23,000 kilos of catfish, 8,000 kilos of tusk and haddock and a small quantity of blue halibut. The small numbers of tusk and of species of the genus *Molva* are remarkable. Cod and catfish take their place. Halibut has been found in great numbers at some places, though it may not be very plentiful in the Barents Sea taken as a whole. On the slopes of small banks north and east of Norway small specimens were caught singly. In 40 fathoms a number of specimens were taken, their lengths varying from 65 to 83 cm. In 128 fathoms halibut from 1.12 to 2.6 metres long were caught east of Vardø.

Statistical Observations.

It may be of interest to compare the information gained by these fishing experiments with the data contained in the fishery statistics. For this purpose

we have prepared the Table 5, which gives the number of tons of the principal species of fish caught during the fisheries along the slope off the Norwegian coast in 1924.

Table 5.

	Cod	Ling	Blue Ling	Tusk	Haddock	Halibut
	tons	tons	tons	tons	tons	tons
Area VI	163	210	0	268	1,150	103
Area VII	188	3,689	955	2,033	724	1,102
District from Area VII to X	913	513	78	852	1,150	911
Area X	142	12	..	97	208	360
Area XI	3,674	0	..	163	14,314	568
	5,080	4,424	1,033	3,413	17,546	3,044
	= 34,540 tons					
Values in thousands of Norw. Kr.	1,215	1,358	345	826	3,363	4,014
	or 11,121,000 Norw. Kroner.					

To avoid any misunderstanding it must be remembered that the cod in the table includes only that part of the catch of cod which was made along the slope. By far the largest catch of cod is made during the spawning season when the spawning cod or skrei collect on the shallower coastal banks or when the great shoals follow the *Mallotus villosus* to its spawning areas. In the year 1924 altogether about 245,000 tons of cod were caught in Norwegian waters. According to the table, however, not more than a little over 2 per cent. of these were caught along the slope.

B. Whales and the Plankton.

The subjects of whaling and the history of whaling in the Norwegian Sea have previously been dealt with by Hjort (1902), S. Risting (1922, 1928) and in a paper in this volume by And. Ingebrigtsen, to which we would refer. Mr. Ingebrigtsen gives a short review of the main facts concerning the appearance and migration of the different species of whales; and expresses his views, based on many years' practical experience as a whaler, on the effects of whaling upon the stock of whales.

In this chapter we propose to consider the facts gathered and the experience gained while studying whales and their food during the last five years. The investigations have been made, partly on the Aukra whaling station off the coast of Möre, partly on expeditions with the "Michael Sars" and the m.s. "Morild" in different parts of the Norwegian Sea.

The investigations off the coast of Möre being by far the most extensive, we propose to consider them first.

1. The Whaling District off the Coast of Möre.

The whaling station on the island called Aukra, at the entrance to the large Romsdal Fjord, is a very modern establishment, including factory equipped with pressboilers and an experimental station for technical research.

The whales are hauled up on a large platform, where they can be measured and studied while the carcasses are cut up.

A small laboratory has been put up for the titration of water samples and the study of plankton.

Fig. 22.

The whaling station owns three small whalers, which can stay at sea for about a week at a time and hunt within a radius of one or two hundred miles.

The investigations under consideration received in some cases very valuable assistance from these vessels but most of the work was done on board the sixty-foot motor cutter "Morild", which, however, had a rather limited field of operations, as the supply of fuel oil was small and with a crew of only three hands she could not stay out at sea for more than a few days.

In the four years during which the Aukra station has been whaling the following whales have been caught. (See table 6).

In every case the statistical observations have been made in accordance with the plan drawn up by Mr. S. Risting of the Norwegian Association of Whalers. Special stress has been laid at this station upon the examination of the contents

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.

Table 6.

Year	Fin-backs	Sei-whales	Blue-whales	Sperm	Total
1925.....	79	101	..	3	183
1926.....	112	73	..	..	185
1927.....	77	37	..	..	114
1928.....	98	41	1	..	140
	366	252	1	3	622

of the stomachs and mouths of the whales. Figures 28 and 29 illustrate very clearly the interest and importance of this investigation, and also the enormous amount of food, even when consisting of such small creatures as the "krill", a whale is able to collect for his daily meal.

The food of the whales caught at Aukra may be classified under the following heads:—

1) Herrings (especially "large" or "spring" herrings), which invade the coastal banks during winter time, mainly for the purpose of spawning.
2) Schizopods which the Norwegian whalers call "krill". The fishermen distinguish between:—
   a) "Stor-krill" (large krill) or *Meganyctiphanes norvegica* and
   b) "Smaa-krill" (small krill) mostly *Thysanoessa inermis.*
3) "Rød-aate" or Copepods, mainly consisting of *Calanus finmarchicus.*
4) Large fish and squids, taken by the Sperm-whale only.

In the statistical lists or journals kept by the laboratory the food of each whale is classified according to these groups.

Fig. 28. Stomach of Finback with Herrings.

Fig. 29. Stomach of Finback with Krill.

An inspection of these lists shows that the sei-whale exclusively or almost exclusively fed on "rød-aate" or *Calanus*; while the fin-back caught herrings, *Calanus*, and the two sorts of krill. The two species of whales should therefore be studied separately.

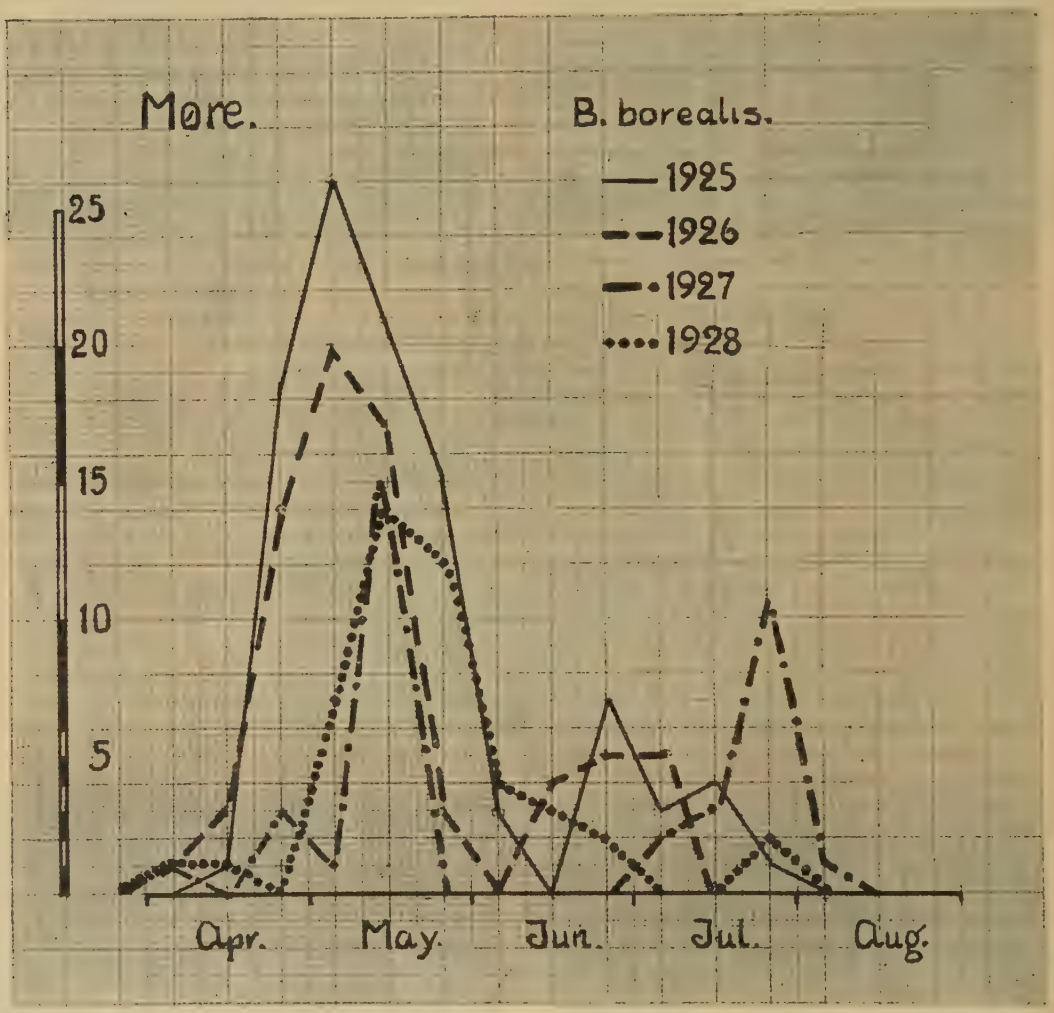


Fig. 30.

The Sei-Whale. If we arrange the observations of the catch of this species according to the seasons, taking each of the four years separately, we may distinguish two periods for the appearance of this whale. The first shows a maximum at the beginning of May and the second in July. There are considerable fluctuations from one year to another. In 1925 and 1926 the sei-whales came earlier than in 1927

and 1928. In 1925 the whales stayed on for a considerably longer period than in the other years.

Seeing that the food of the sei-whale is found to consist almost exclusively of the "rød-aate" or *Calanus*, it seems natural to compare the appearance of the sei-whale with the quantitative occurrence of *Calanus finmarchicus* in the waters of the coastal banks and slopes where the sei-whales were caught.

The material for this comparison is given in the paper by Ruud (in this volume) which furnishes precise estimates of the numbers of *Calanus finmarchicus* present on the banks at different seasons of the year in which investigations were made.

In Figure 31 the two series of observations (the number of whales caught and the number of *Calanus finmarchicus* present in the samples of plankton collected from the coastal banks) are compared for the different months of the fishing period of 1926.

It will be seen from the figure that there is a distinct parallel between the two series of observations. The great and rapid development of *Calanus* precedes, by a short time, the appearance of the sei-whale.

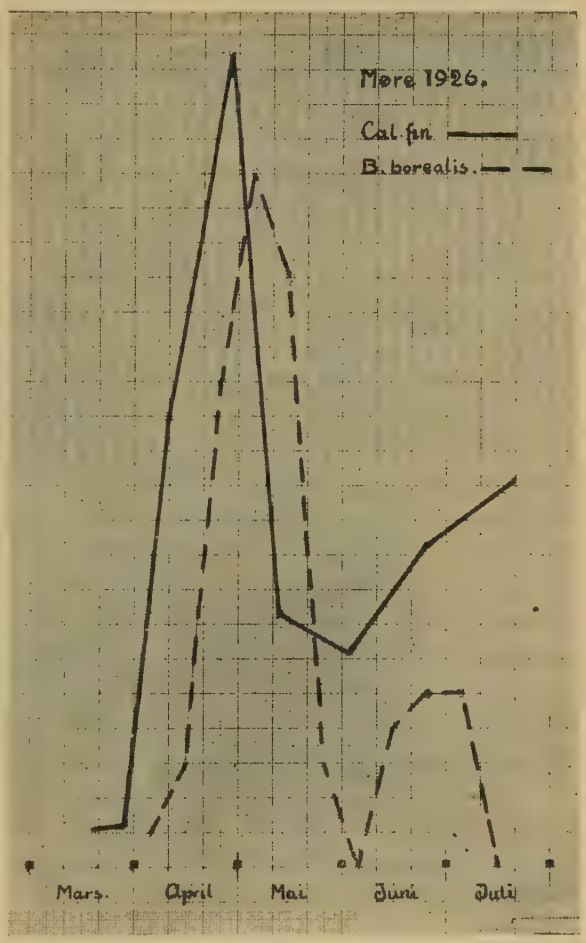


Fig. 31.

The statistical lists of the station include a record of the place of capture of each whale. On the basis of these records a chart, Fig. 32, has been drawn, giving all observations for the years 1926 to 1928.

Of great interest is also the comparison between Figure 30, which shows the fluctuating catches of sei-whale from year to year and Figure 2 in Ruud's paper (page 14). There seems to be a distinct parallelism in the fluctuations of the two sets of observations, but unfortunately our material does not permit of any close and complete comparison, as the observations, especially in 1925, the most important year, were too few.

It will be seen from Figure 32, that all the places of capture are along the slope of the bank, partly along the slope facing the great deep outside the continental shelf, and partly on the slope down to a deep plain north of the shallower bank itself.

In Ruud's paper the quantitative distribution along the different parts of the bank is discussed at some length. Fig. 33 has been drawn on the basis of the quantitative data from each station. It shows a marked increase in the number of *Calanus finmarchicus* in the direction of the slope of the bank.

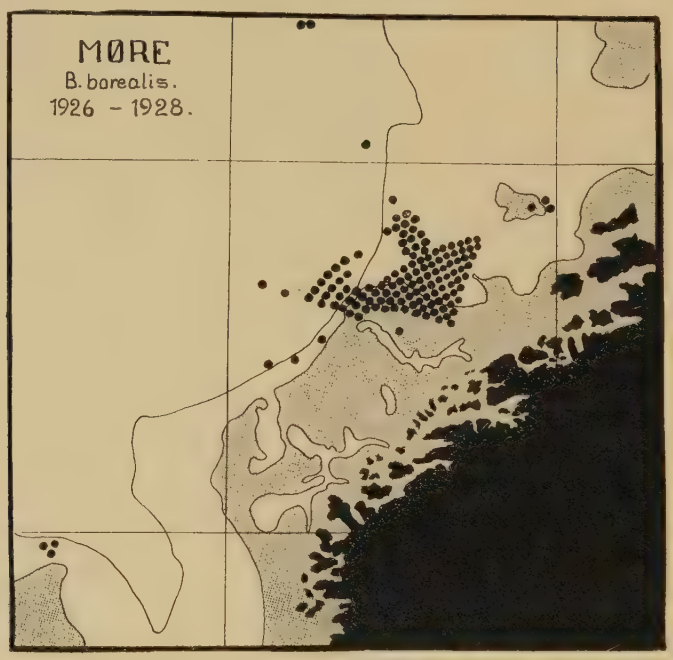


Fig. 32.

The Finback. In all the curves for the four years there is a very clear distinction between winter fishing and summer fishing. Some finbacks are caught between the middle of January and the end of March. During this time the food of the finbacks was, in all years, either herrings or the small krill, *Thysanoessa*. In April and the early part of May the finbacks either caught *Calanus* or the small krill, but there was always very little animal life present on the bank during these spring months. From the middle of May to the end of the season, i.e. about the middle of August, we have the "summer fishing", during which the finbacks live exclusively on the large krill, *Meganyctiphanes norvegica*.

Regarding the geographical areas in which the finbacks were caught, we must again distinguish between the two periods, i.e. the winter and the summer fishing.

The small chart, Fig. 38, shows the area of the winter fishing. During this period the finbacks are taken far in on the bank. It will be observed that most of the places are situated near or around the channels or deep valleys which are very characteristic of the small Norwegian coast-banks.

The fishing during the summer is of a very different character, as will be seen from the chart, Fig. 39. In summer the finbacks frequent very much the

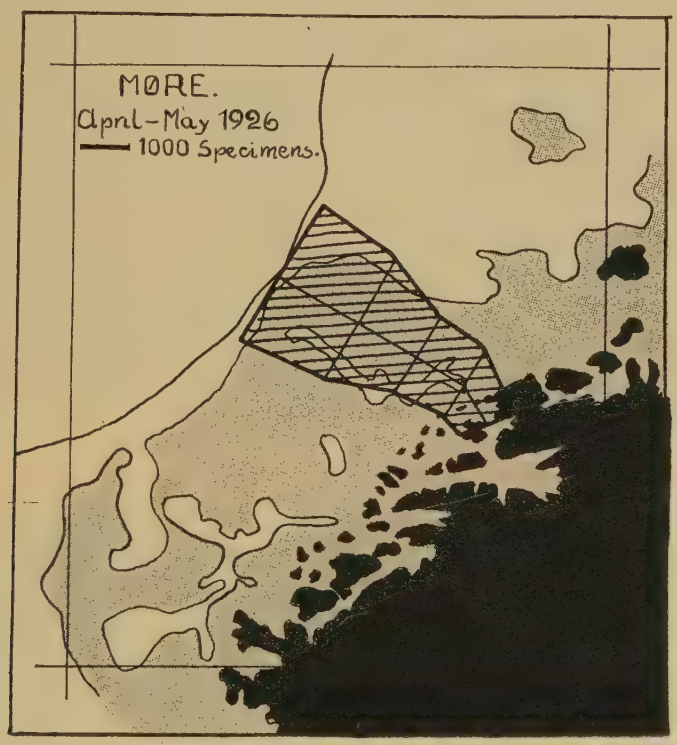


Fig. 33.

same ground as the sei-whale. Those which were caught were all on the slope of the Continental Shelf, on the North slope of the bank, or on the slope of the North Sea Bank (Tampen).

The Biology of the Schizopods or Krill

has been much studied during our plankton investigations, in the hope of explaining these peculiarities in the seasonal and local appearance of the finback. We will mainly confine our attention here to the facts observed, reserving the fuller discussion of all these obviously correlated phenomena for our concluding chapter.

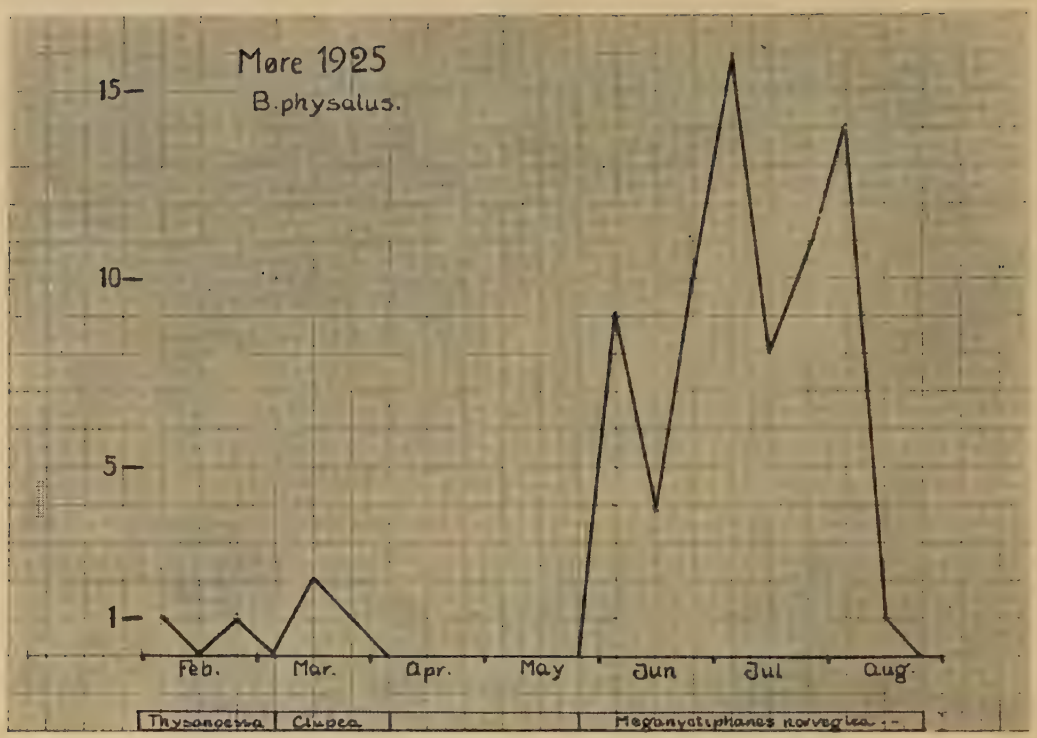

Møre 1925
B.physalus.
15—
10—
5—
1—
Feb.
Mar.
Apr.
May
Jun
Jul
Aug.
Thysanoessa
Clupea
Meganyctiphanes norvegica

Fig. 34.

Møre 1926
B. physalus.
10-
5-
1-
Jan.
Feb.
Mar.
Apr
Mai
Jun
Jul.
Aug.
Åte —
Clupea
Thysanoessa
Calanus
Meganyctiphanes norv.

Fig. 35.

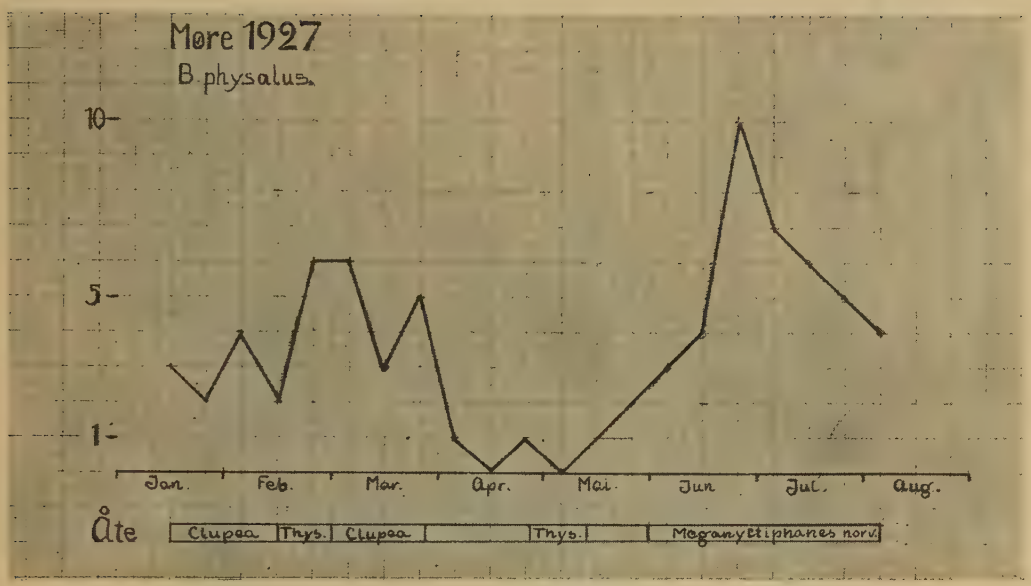

Møre 1927
B. physalus.
10-
5-
1-
Jan.
Feb.
Mar.
Apr.
Mai
Jun
Jul.
Aug.
Åte
Clupea
Thys.
Clupea
Thys.
Meganyctiphanes norv.

Fig. 36.

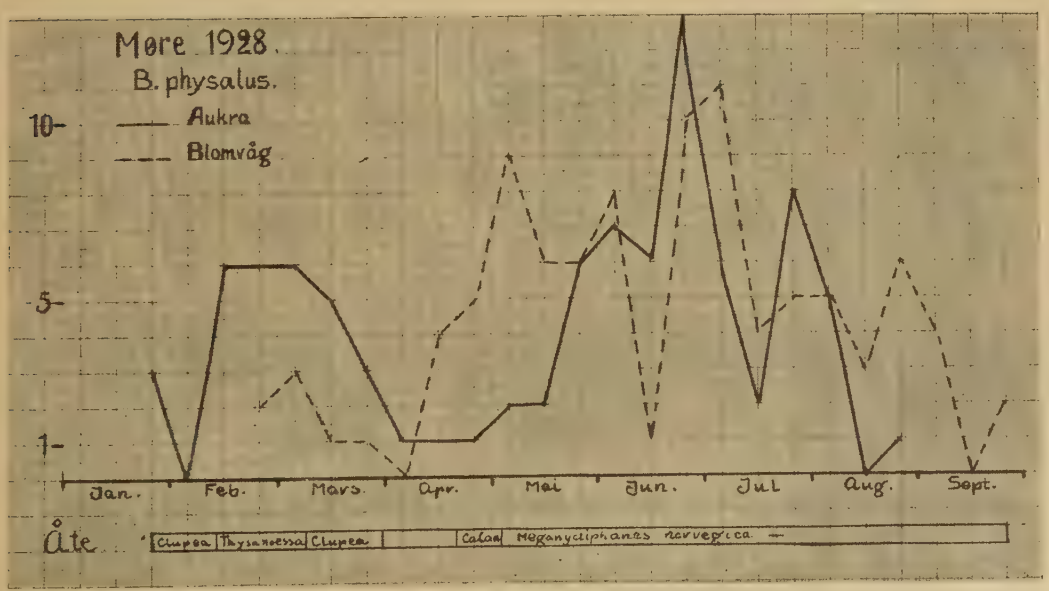

Møre 1928.
B. physalus.
Aukra
Blomvåg
10-
5-
1-
Jan.
Feb.
Mars
Apr.
Mai
Jun.
Jul
Aug.
Sept.
Åte
Clupea
Thysanoessa
Clupea
Calan
Meganyctiphanes norvegica

Fig. 37.

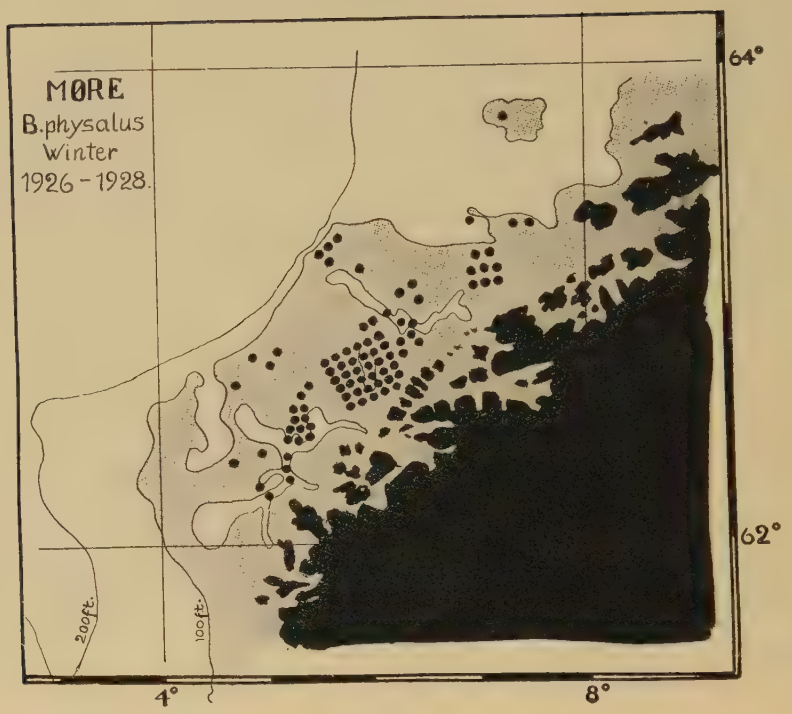


Fig. 38.

In the Möre region the following species of euphausiids are common:—

Meganyctiphanes norvegica M. Sars,
Thysanoessa inermis (et *neglecta*) Kröyer,
Thysanoessa raschi M. Sars,
Thysanoessa longicaudata Kröyer.

Occasionally the following are found:

Euphausia mülleri Claus, and
Nyctiphanes couchi Bell.

The two first of these species occur in particularly large quantities, *Meganyctiphanes norvegica* in summer and *Thysanoessa inermis* in winter; these are the kinds which the whalers call large krill and small krill respectively.

Both species are present, however, in this region all through the period subjected to investigation, i.e. from March to September, and most probably all the year round. There is a characteristic difference between the two species as regards their geographical distribution.

Although both are found throughout the region, *Meganyctiphanes norvegica* evidently reaches its maximum numbers over or near the slope, whereas *Thysa-*

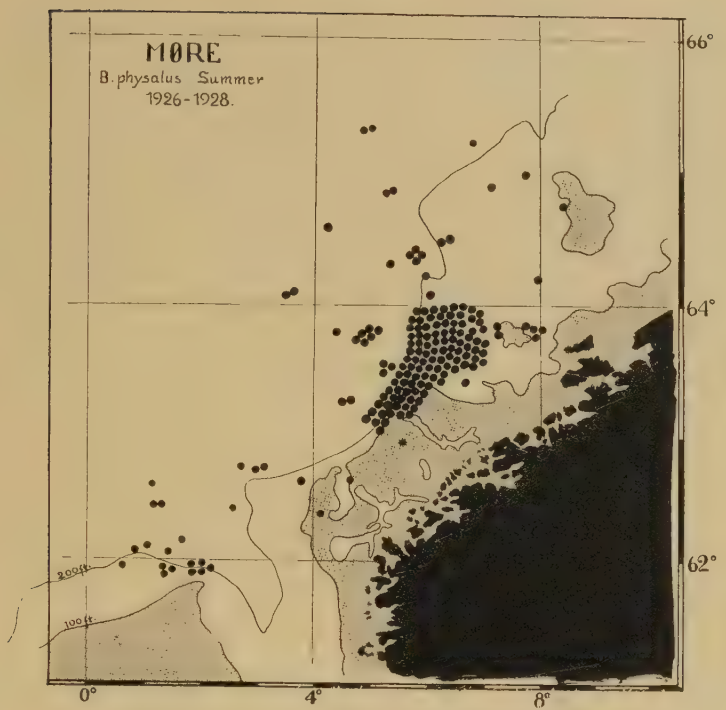


Fig. 39.

noessa inermis is found in largest numbers on the coastal bank, or rather above the deep channels in the bank off the coast of Möre.

This state of things may, perhaps, be best illustrated by the subjoined table, which represents two tow-net catches taken in March, the first on the bank in 1926, the second out at Eggen in 1928.

Table 7.

	Station 41 17/III 1926	Station 209 27/III 1928
Meganyctiphanes norvegica	22	139
Thysanoessa inermis	124	25
Thysanoessa raschi	..	5
Thysanoessa longicaudata	..	122
Nyctiphanes couchi	7 (juv)	..
Euphausia mülleri	..	1 (juv)

This table shows that the arctic boreal form *Thysanoessa inermis* predominates on the bank, while the euphausiids found farther out at Eggen are Atlantic in character.

St. 209 in the table shows that *Meganyctiphanes norvegica* may be present

in large quantities even early in the year, and whales are occasionally caught at that time with *Meganyctiphanes* in the gullet and stomach. The whales examined, however, were caught near Eggen, whereas nearly all the winter hunting of the fin-back normally takes place far in on the bank, where they always contain *Thysanoessa inermis* when their food is "krill". On the other hand the fin-backs caught in summer contain almost exclusively *Meganyctiphanes norvegica.* If we compare this with the charts showing the winter and summer catches of fin-back whales (Fig. 38 and Fig. 39), we get an excellent idea of the difference between the two most important kinds of "krill" as regards their geographical distribution in the region under consideration.

The material from Möre includes samples of 109 tow-net catches, and it is remarkable that only 19 of them show a positive result as regards post-larval euphausiids. The hauls were mostly made with a fine-mesh 70 cm. diameter net, which means that the hauls had to be of short duration — five or ten minutes. The perfectly natural explanation of this is that the euphausiids usually congregate in dense, separate swarms, which we have sometimes seen as patches on the surface. Away from these swarms the euphausiids are only caught occasionally, and then almost exclusively deep down or near the bottom.

We have examined euphausiids in rich tow-net samples, or taken from the oesophagus of finbacks, with regard to their sexual maturity, hoping thereby to get a step nearer to the solution of the problem as to what causes the formation of these swarms of euphausiids.

In all the cases examined the euphausiids caught were sexually mature, to such an extent, indeed, that spawning had certainly taken place or was about to do so. This is true, for instance, of the two samples in the table.

At Station 41 the sample contained not only sexually mature euphausiids but quantities of eggs in early stages of cleavage, and nauplii. The females of *Thysanoessa inermis* had large and well-developed ovaries with large eggs; they had spermatozoa in the spermathecas, and the majority had also spermatophores affixed. The males had well-developed spermatophores. As regards *Meganyctiphanes norvegica* the females in this sample had large ovaries, but eggs which were not quite mature. The spermatophores of the males were not fully developed.

The sample on Station 209 was taken with a stramine net, and consequently contained no eggs or nauplii. The females of *Thysanoessa inermis* had large ovaries containing eggs which were not fully mature. Some had spermatophores and many had spermatozoa in their spermathecas. The females of *Meganyctiphanes norvegica* had ovaries with a few large eggs. Many of the females had spermatozoa in their spermathecas, and one female had also spermatophores affixed. The males of both species had well-developed spermatophores.

Examples could be multiplied from the tow-net hauls, but the fullest material for this investigation has been obtained by examining "krill" taken from the

oesophagus of the finback. Sixteen samples of this kind have been examined, taken from the years 1927 and 1928, and during the months from March to August. The results obtained from two samples, selected at random, are given below:—

1) Sample from finback No. 17 March 1st, 1928. Shot W. of Stadt 18′. *Thysanoessa inermis*, examined 4 females and 6 males. All females with well-developed ovaries with large eggs. All with spermatozoa in the spermathecas and 3 with spermatophores affixed. 6 males with well-developed spermatophores.
2) Sample from finback No. 62 June 19th, 1927. Shot at Storeggen. *Meganyctiphanes norvegica*, examined 6 females and 4 males. All females with large mature ovaries and spermatozoa in the spermathecas, one with spermatophores affixed. Males with well-developed spermatophores.

These examples show that whenever the "krill" occurs in sufficient density to be caught in considerable numbers in nets, or to be eaten in such quantities by whales that we can get good fresh samples from the oesophagus, we may assume that pairing or spawning has taken place.

This is quite natural when we remember, what every whaler has noticed, that "krill" as whale-food occurs spontaneously in certain places and particular masses of water.

The analysis of *Meganyctiphanes norvegica* at Station 209 proved that this species is able to spawn quite early in the year, even if it is undeniably true that most of the spawning takes place in summer. We have found, too, in each year of this investigation, larval stages of *Meganyctiphanes norvegica* as early as April—May in our vertical hauls, though the numbers have been small.

Whalers and fishermen are well aware that the quantity of "krill" varies greatly from year to year. There is absolutely no doubt, for instance, that the quantity of *Meganyctiphanes norvegica*, judged by the amount in the stomachs of the whales, was decidedly greater in 1928 than in any of the previous years.

We have no exact method of proving this, as the catches by means of tow-nets are too much subject to chance variations to be suitable for this particular purpose. Yet there is certainly a connection between the quantity of post-larval "krill" and the quantity of larvae in the preceding year, if, as we believe, the "krill" develops in one year in these waters.

In an earlier article Ruud (1928) has shown that the quantity of *Meganyctiphanes norvegica* larvae was unquestionably greater in 1927 than in 1926 in the Möre region. Accordingly a profusion of *Meganyctiphanes norvegica* was anticipated in 1928, although our researches had not yet gone far enough to justify us in predicting it.

The investigations in 1928 will not admit of our using the tow-net material for further research along these lines, as no investigations were made during the months of April, May and June — a period of special importance for the larvae.

The vertical net-hauls constantly contain eggs and larvae of euphausiids, but there is a certain periodicity and regularity in the appearance of the various stages. Up to the present we have not got a sufficient number of exact statistics to give the material in tabulated form; we can therefore only indicate the main characteristics.

In the first samples taken annually in March there are always some eggs of euphausiids, and the maximum is obviously attained farther in on the bank. Undoubtedly these eggs belong, to a large extent, to spawning *Thysanoessa inermis*, of which there are great numbers present in these waters.

The quantity of eggs in this place culminates at the end of March or beginning of April, but small numbers of eggs are found throughout the whole period of the researches on several stations, including the bank, but chiefly and most frequently out at Eggen. There is no noticeable culmination in the number of eggs at the outermost station; spawning seems to be more regular and continuous all through the spring and summer.

We may regard it as certain that the eggs at this outlying station mainly belong to *Meganyctiphanes norvegica*, which occurs in profusion from May onwards at and near Eggen. Comparing this with the chart of finbacks caught in summer (Fig. 39) we are probably correct in assuming that the outermost station at Storeggen is on the border and to the south of the most important spawning area of the *Meganyctiphanes norvegica*. The current here runs north-east, which explains why comparatively small quantities of eggs, and even smaller quantities of the subsequent larval stages, are found at our outermost station.

Nauplii and metanauplii of euphausiids are usually found in our material together with the eggs, and, as we should expect with a relatively short ontogenesis, their number often culminates in the samples which at the same time show a maximum of eggs, i.e. those taken in March—April on the bank. The total quantity of nauplii found out at Eggen has been small.

In the calyptopis stages *Meganyctiphanes norvegica* can be identified easily and with certainty; and it then appears that the bulk of our calyptopis stages belong to *Thysanoessa* sp. — evidently *Thysanoessa inermis* for the most part — and that they are chiefly found on the bank. No calyptopis stages have been found in samples taken earlier than the end of March, and the numbers on the bank culminate in April. The small numbers of calyptopis found in June and July are chiefly *Meganyctiphanes norvegica*. Of this species there were, on the average, more in this stage of development in the vertical samples of 1927 than there were in the samples of 1926. The same thing has already been observed by Ruud in regard to tow-net samples (Ruud 1928).

The succeeding stages of development are only present in small numbers in the vertical samples. A few furcilia stages of *Thysanoessa* sp. have been found as early as the end of March, but they are not common before the beginning of

May. The largest quantity of furcilia and cyrtopia of *Thysanoessa* sp. are always found on the bank.

Furcilia stages of *Meganyctiphanes norvegica* have not been found in any year earlier than the beginning of May; these and the cyrtopia stages are most numerous in June and July, especially farthest out on the bank and at Eggen.

Post-larval euphausiids are only very rarely taken in vertical net-hauls, and then only at night during the early months of spring.

It will be seen from the above observations that our material shows very clearly that there are two different and separate spawnings of the euphausiids in the region investigated.

The first spawning, that of *Thysanoessa inermis*, on the inner part of the bank, lasts a comparatively short time, and the various stages of development are found to succeed each other with regularity during the spring and summer.

The larvae that we come across in the area of investigation has, of course, been spawned to the west and south, where we may assume that spawning takes place earlier; thus our material gives a time-foreshortened picture of the development of the euphausiids, similar to that which RUUD gives in the case of the copepods (RUUD, in the present volume).

Basing our judgment more especially upon the catch of finback whales, we draw the conclusion that the spawning of *Meganyctiphanes norvegica* goes on for a prolonged period, and that the most important spawning area is to the north-east of our line of observation. This is why we do not see much of the larvae of this species in our samples.

2. The Southern Slopes of the Norwegian Sea.

Very few investigations have been carried on with the object of ascertaining what is the food of the whales along these southern slopes of the Norwegian Sea. The material at our disposal is not very large, but nevertheless it seems to suggest certain conclusions. We shall therefore state very briefly the more important facts.

During the voyage of the "Michael Sars" to and from Davis Strait in 1924, a series of Plankton investigations was made for the special purpose of collecting information about the distribution of the species which form the food of the fin-backs.

Owing to the nature of the voyage the material is comparatively limited, but it exhibits certain characteristic features. In the south of the Norwegian Sea — the Norway-Shetland-Faroe Island area — the stations on the bank showed remarkably poor results or were completely negative as regards Schizopods. In contrast to these the stations on the edges were all rich in them, some, indeed, being very rich, considering that the material was obtained by vertical hauls with such a small net as our standard net of 70 cm. diameter.

The chart (Fig. 40) gives in the form of a diagram the results obtained at the "Michael Sars" stations compared with the catch of fin-backs off the Faroes. This diagram represents the total of all species; and the figure illustrates the abundant quantities taken at Stations 5, 70, 72 and 74 — in other words the stations on the edges — in contrast with the other stations.

The only species found in this area were *Meganyctiphanes norvegica* (M. Sars), *Thysanoessa inermis* (et neglecta) (Kröyer) and *Thysanoessa longicaudata* (Kröyer). The last-named species is the most common in vertical net-hauls; it is found in them all, and in great numbers in most of the positive samples. *Meganyctiphanes norvegica* was taken at Stations 4, 5, 9, 12, 70, 71, 72 and 74, in considerable numbers only on the edges. *Thysanoessa inermis* was taken singly at Stations 12 and 70, and in slightly larger numbers at Station 74 near the North Sea Reef. In this connection it may be mentioned that the stations on the edges were all worked in the dark, as was also St. 9.

At Station 70 at the edge of the Faroe bank a series of tow-net hauls was made, all very rich in the three species of euphausiids, especially *Meganyctiphanes norvegica*. In these samples (taken in September) there are no larval stages of euphausiids. The samples from Stations 70 and 74, containing *Meganyctiphanes norvegica*, were partially examined in order to determine the degree of sexual maturity. It was found that all the males examined had well-developed spermatophores, some of which were quite loose. The ovaries of the females were quite large, but there were no mature eggs. Some of the females had spermatozoa in their spermathecas, showing that they had been fertilized. In view of this it appears probable that *Meganyctiphanes norvegica* can spawn far on in the autumn in these waters. Mr. J. D. Sømme informs us that one night in August 1924 in the Faroe-Shetland Channel he observed krill swarming on the surface, and Plankton samples taken on this occasion by the s.s. "Explorer" show *Meganyctiphanes norvegica* together with a profusion of eggs.

North of the Faroes, on and near the Faroe-Iceland ridge, a number of stations were worked, but only the tow-nets furnished positive results as regards euphausiids. At Station 19 tow-nets were used with 250 m., 500 m., 1000 m , and 2000 m. wire. The three last hauls took some euphausiids, especially the deepest, which contained two or three thousand specimens, 95 per cent. being *Meganyctiphanes norvegica* and 5 per cent. *Thysanoessa longicaudata.*

In the sample taken with the 500 m. wire there were 41 specimens of *Thysanoessa inermis*, 19 of *Thysanoessa longicaudata* and 5 of *Meganyctiphanes norvegica* (young specimens).

This distribution as regards depth is very interesting in connection with the conditions at Station 15, where "rød-aate" taken at the surface included, *inter alia*, between three and four hundred specimens of *Meganyctiphanes norvegica*. We shall enter more fully into these facts, which may appear to conflict here, in Chapter III.

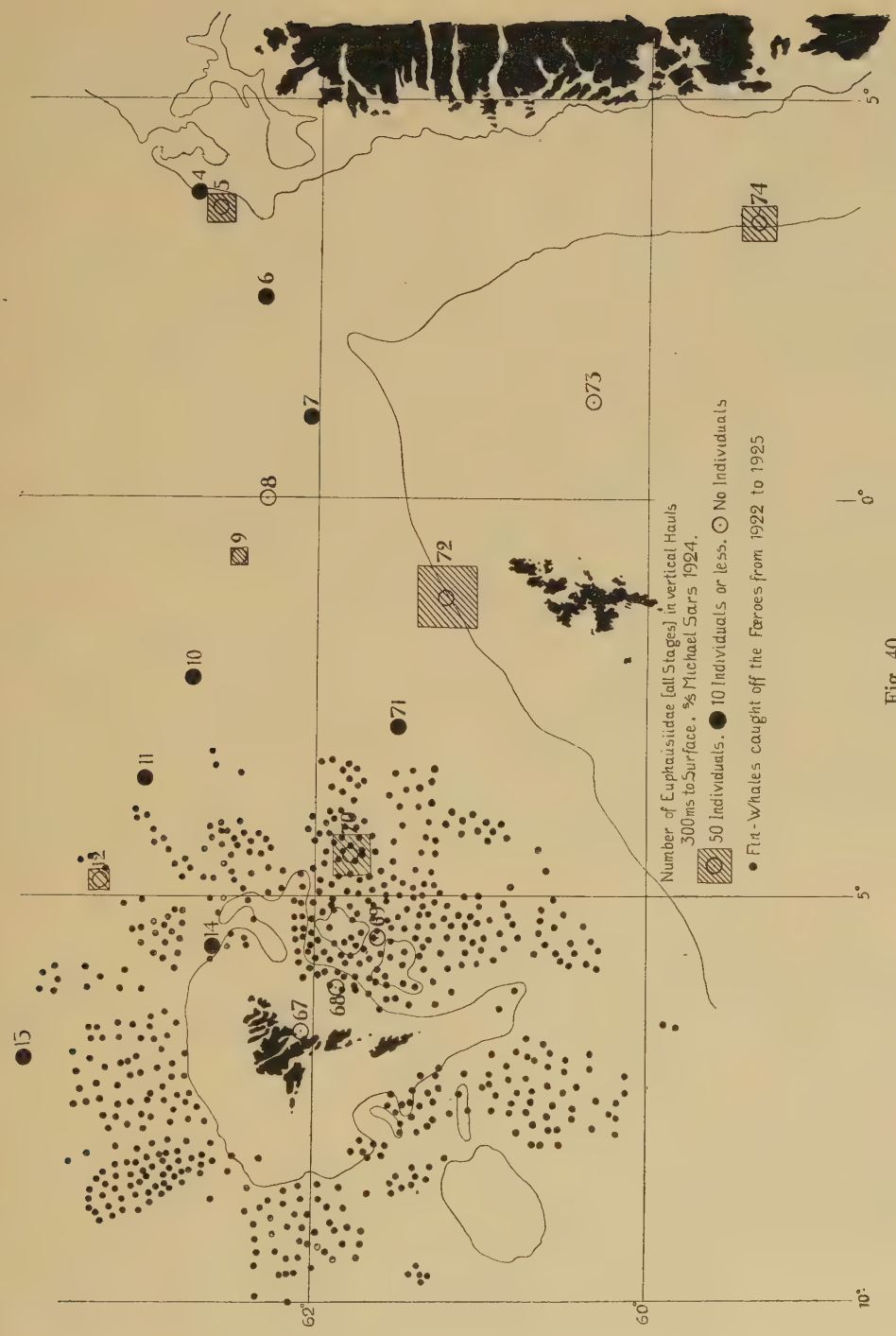

Number of Euphausiidae (all Stages) in vertical Hauls 300ms to Surface. %s Michael Sars 1924.
50 Individuals. 10 Individuals or less. No Individuals
Fin-Whales caught off the Faroes from 1922 to 1925
62°
60°
10°
5°
0°
5°

Fig. 40.

In the North Atlantic between the Faroes, Iceland and Greenland the following species were found: *Meganyctiphanes norvegica* and *Thysanoessa longicaudata*, in company with the Atlantic forms *Thysanopoda acutifrons* (Holt and Tattersall), *Euphausia mülleri* (Claus), *Nematoscelis megalops* (G. O. Sars), *Nematobrachion boopis* (Calman), and the *Mysidacea: Eucopia unguiculata* (Willemoës-Suhm), *Gnathophausia zoea* (Willemoës-Suhm), and *Boreomysis microps* (G. O. Sars). *Thysanoessa inermis* was not taken in these waters.

One feature common to these samples is the fact that the adult *Meganyctiphanes* and *Thysanoessa longicaudata* were found, almost without exception, in deeper water than 500 m. in company with other species belonging to the deep Atlantic. The larval stages, on the other hand, were only found above 50—100 m. and also on the Iceland Bank. But in any case only small quantities were obtained by these vertical hauls. The characteristic deep water distribution was most clearly seen at the stations between Iceland and Greenland, where *Thysanoessa longicaudata* was present in comparatively large numbers below 500 m., in company with *Eucopia*, *Gnathophausia* and *Boreomysis microps*. The last-named species which belongs to the deep Atlantic, was also found in the 50—0 m. haul at Station 31 near Cape Farewell, where the upper layers of water afford temperature conditions similar to the deep water at the previous stations.

In Skager Rak the "krill" has been studied by Dr. O. Nybelin of the Swedish Hydrographical and Biological Commission, who has kindly furnished us with his observations on the material so far collected. The following species have been found there: *Meganyctiphanes norvegica*, *Nyctiphanes couchi*, *Thysanoessa inermis* (et *neglecta*), *Thysanoessa longicaudata*, *Thysanoessa raschi* and *Nematoscelis megalops*. Only *Meganyctiphanes norvegica* and *Thysanoessa raschi* are found, occasionally, in large quantities in the samples taken. All the samples are from tow-net hauls, and nearly all were taken at night. Hauls in the daytime show, almost without exception negative results.

Concerning *Meganyctiphanes norvegica* Kramp (1913) writes: "In the Skager Rak *M. norvegica* is nearly always common, especially in November and February. The shoals occurring in the Skager Rak have undoubtedly immigrated from the Norwegian Sea. It occurs together with such originally Arctic forms as *Diphyes arctica*, *Aglantha digitalis*, *Krohnia hamata* etc. in the cold layers of the water. Young specimens are found in the Skager Rak in August".

In the inner Skager Rak the occurrence of *Meganyctiphanes norvegica* is evidently limited by the depth conditions, as it is only taken exceptionally in shallower water than 100 m., and in such cases always near the deep water. Observations for the months from April to November are lacking, but during the period investigated *M. norvegica* seems to increase in numbers at the inner stations from November to January—February, after which it decreases again. It may, however, be found all the year round, as this species is stationary in the deep water of the

Norwegian Channel. In August there is, according to the statement of Dr. Nybelin, a stock of mixed lengths, as post-larval specimens (10—12 mm.) are found in company with adult individuals (25—30 mm.). The samples obtained have been taken in all temperatures between —0.38° and +8.30°, but as a rule between +3° and +7°. The salinities where *M. norvegica* has been taken are all over 30 ‰, and, in the deep water at these stations, over 34.5 ‰. This may possibly indicate that it accompanies Atlantic water, and not Arctic water, as Kramp suggests.

M. norvegica is constantly present in the stomachs of the herrings caught by Swedish fishermen in these waters, and Nybelin holds that there is unquestionably a connection between the amount of *M. norvegica* and the influx of the herring.

Large quantities of *Thysanoessa raschi* are often found with *M. norvegica*. When the former is found alone at the shallower stations the numbers are invariably small.

Nematoscelis megalops is only found occasionally. Except in two cases it has always been found in samples containing large quantities of *M. norvegica*. The oceanic Atlantic character of this species likewise points to water of Atlantic origin. The other species also occur in small numbers only, but they are generally present in all the samples. *Nyctiphanes couchi* spawns, according to the observations made by Dr. Nybelin, in Skager Rak. The young specimens of it that we have occasionally found in our samples in the Möre area were presumably carried thither by the Baltic current from Skager Rak, the nearest known spawning ground.

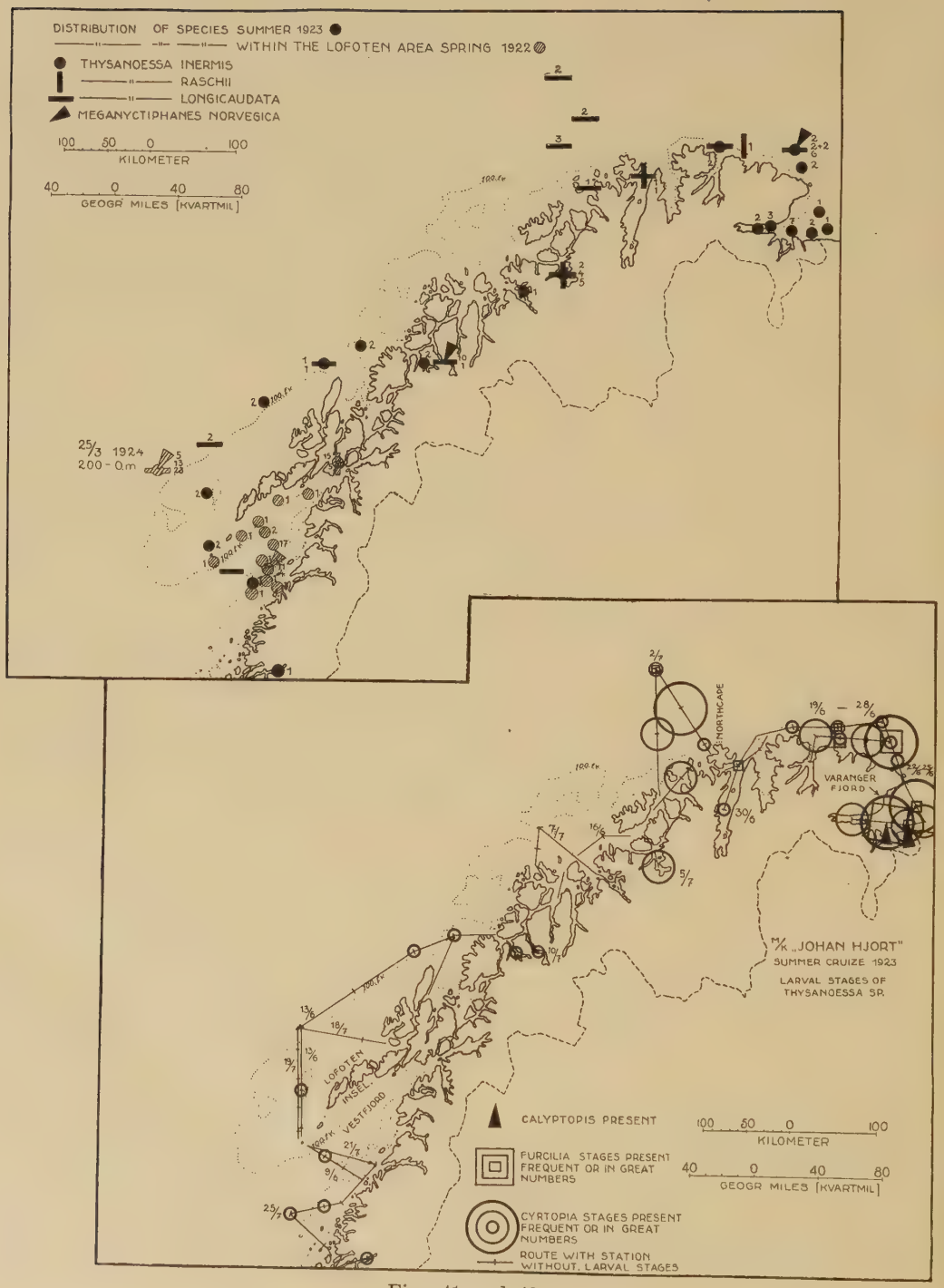
In his study of the euphausiids in the southern Norwegian fjords G. O. Sars (1898) gives no statement as to the relative distribution of the different species. According to information from Mr. J. D. Sømme the *Thysanoessa raschi* is the most common species in the Oslo fjord. *Meganyctiphanes norvegica* and *Thysanoessa longicaudata* are, however, generally met with in the fjord.

3. The Northern Slopes of the Norwegian Sea.

For this area Mr. J. D. Sømme has kindly placed at our disposal his observations on the material with which he was furnished by the Director of Fisheries. The material in question was collected in the spring of 1922 at Lofoten, and in the summer of 1923 at Lofoten and in the sea off Finmark.

The distribution and the numbers found of the euphausiids concerned is shown in Fig. 41.

Thysanoessa inermis (et *neglecta*) Kröyer is the commonest species in these waters. It is found in the greatest quantities in the fjords and very near the coast, though it is usually found at some distance from the coast as well. On the expedition in the spring of 1922 large quantities of euphausiids and larvae were found in Vestfjord. Fig. 43 gives the number of eggs per 5-minutes surface haul at the stations investigated. There are eggs throughout the whole of this area, but they are most



Figs. 41 and 42.

numerous on the east side of the mouth of the fjord. This part was particularly rich in eggs on each of the three occasions when investigations were made there in April. In all probability we have here a limited area within which the spawning of *Thysanoessa inermis* proceeds vigorously. Sexually mature females of this species, with large eggs in their ovaries and spermatophores affixed, were found in the same place at the same time.

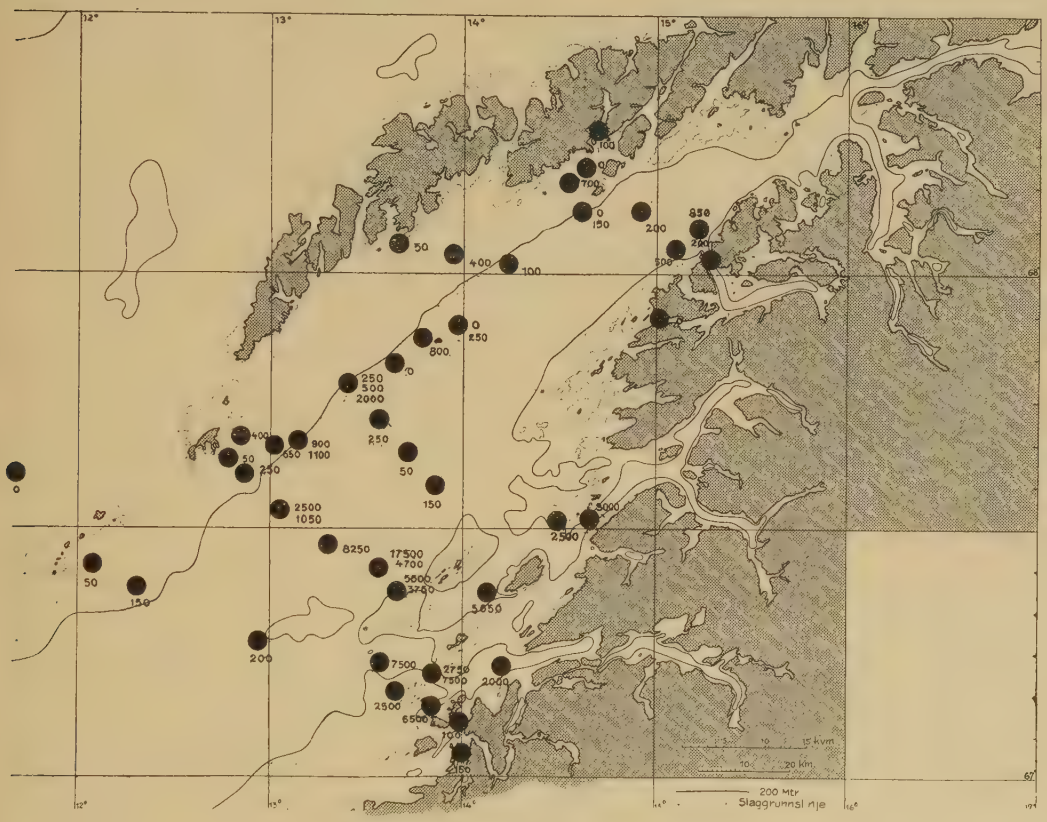


Fig. 43.

On the summer expedition in 1923 no eggs, nauplii or metanauplii of euphausiids were found. The results obtained by counting the various larval stages are given in Fig. 42. It will be seen that only a small number of larvae and no stages earlier than the cyrtopia stages were found in the Lofoten area. The greatest quantities of larval stages — all belonging to the *Thysanoessa* — were found in Varanger fjord, where even such early stages as calyptopis and furcilia were present, though here, too, the cyrtopia stages were the most common. In company with this larvae comparatively large quantities of *Thysanoessa inermis* were found; so there are grounds for supposing that this species is chiefly responsible for the

spawning in Varanger fjord as well, though this spawning must have taken place later than the spawning in the Lofoten area.

Thysanoessa raschi M. Sars. Only a few specimens were taken in this area; there were only 11 in all in the entire material. Evidently it plays a much less important part than the preceding species.

Thysanoessa longicaudata Kröyer. Quite a large quantity was found in the summer, but not in the coastal waters in spring-time. It was found, however, early in the year far out at sea (in Atlantic water). Far out on the west Finmark banks large quantities of certain larval stages were found in the summer, and most probably these belonged to the above species, as it is the only Thysanoessa of which adult specimens have been found in this place.

Meganyctiphanes norvegica M. Sars. This species was not found to any great extent in the area, although quite large numbers were encountered on two occasions far out at sea near Eggen, and it occurred singly in a couple of samples from the fjords. No larvae of this species were identified.

According to the available literature it appears that *Thysanoessa inermis* is the commonest species to the east in the Barents Sea, in the fjords of Spitzbergen and elsewhere in the Polar Sea. *Thysanoessa raschi*, however, is frequently found, for instance in the Kola fjord; and *Thysanoessa longicaudata* and *Meganyctiphanes norvegica* have been met with singly far into the Polar Sea. (Bjørk 1916, Derjugin 1915, Linko 1913, Sars 1900, Zimmer 1904).

C. Review of the Whaling Grounds of the Continental Shelf of the Norwegian Sea.

Modern whaling based on the catch of fin-back whales started in Finmarken, the most northerly county of Norway, in 1864, and was carried on there till 1903. On the chart, Figure 44, the positions of all the whaling stations of this period are marked. It will also be seen that the curves for 200 and for 400 metres' depth run parallel, and rather close to the coast line and even into some of the fjords, especially the large Varangerfjord. The whaling started in this fjord and was gradually extended all along the coast to the west and later on to Bear Island. In all these localities whaling took place mainly on the slope.

Particulars of the appearance and migrations of the different species of whales are given in Mr. Ingebrigtsen's paper. In this chapter we shall mainly confine our attention to such particulars as are of interest for purposes of comparison with the experience gained in the investigations off the coast of Möre (see also Hjort 1902).

The first activities of the great pioneer and organiser of this industry, Mr. Svend Foyn, were entirely confined to catching blue-whales in the Varangerfjord. The blue-whales arrived in the waters of Finmarken in very small numbers

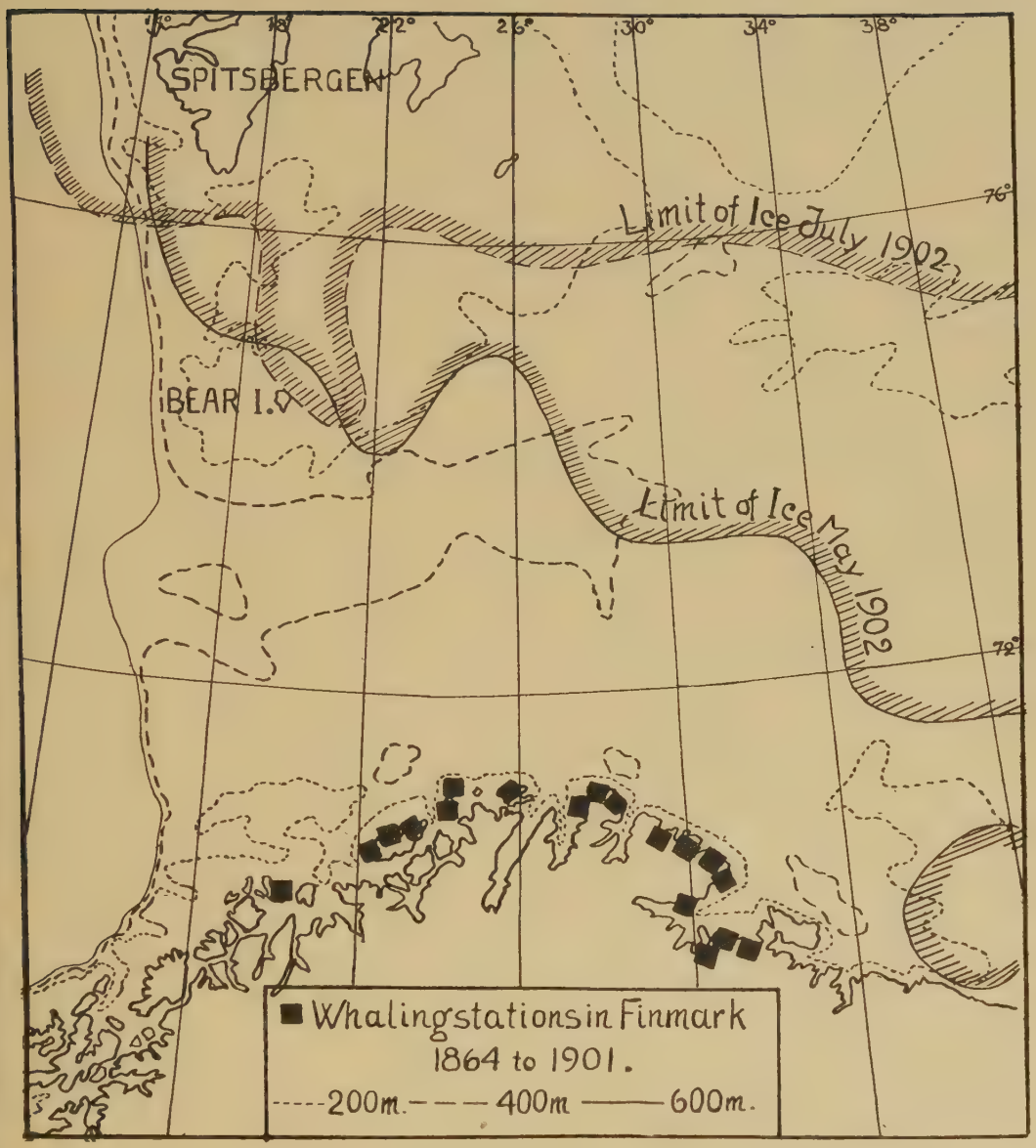


Fig. 44.

in the latter part of May, followed by more in June and the great bulk in July. At the end of July the number decreased, after which some were taken in August and, very seldom, a few in the first few days of September.

The food of the blue-whale was investigated by G. O. Sars (1874), who states that the species to which the catches of Mr. Foyn are exclusively or

mainly confined, the so-called blue-whale, has nothing to do with the "lodde" or caplin (the *Mallotus villosus*). According to repeated investigations which he made, the contents of its stomach consist almost exclusively of a small, transparent crustacean (*Thysanopoda inermis*) which is called "krill". He never found herrings in the stomachs and Mr. Foyn assured him that he was never able to discover either "lodde" or herring in their stomachs.

This would explain:—

1) why the blue-whales were absent in the winter or spring, when the fin-backs follow the "lodde" (*Mallotus*),
2) why the appearance of the blue-whale coincides with the spawning time of the species of Schizopod, which plays the sole or at any rate by far the chief rôle in these northern waters.

When the catch of blue-whales diminished off the coast of Finmarken it continued for some years off the coastal bank of Bear Island. Mr. Ingebrigtsen, who personally took part in this whaling, writes in his paper (in this volume), that in the month of June the temperature of the sea around Bear Island near the land was 0° C. or —0.5° C. But the temperature increased gradually to the west, and between 30 to 40 miles west of the island the temperature was from 3° to 4° C. At this place the "krill" was present all the summer and it attracted hump-back, fin-back and blue-whales.

Both the fin-backs and hump-backs were caught in Finmarken in two different periods, as was the case with the fin-backs off Möre. We may distinguish between the winter fishing, when these two sorts of whale follow the shoals of "lodde", and the summer fishing based on "krill".

It is of great interest that these two kinds of whale spent the whole of the autumn and part of the winter far to the N.E. of the Barents Sea, where they followed the lodde right up by the great border of the floating ice.

The Sei-whale was never very plentiful in Finmarken waters and its appearance, like that of the blue-whale, was confined to the summer months, mainly between June and August.

Collett states (1912) that the contents of the stomachs were "rød-aate", i.e. the *Calanus*, and that the latest date at which it was ever observed up to the year 1885 was the 8th of September.

At the beginning of this century Hjort (1902) carried out some preliminary investigations of the quantitative increase of the stock of *Calanus* after the winter months, when very few specimens were present. The period of the great development started in April and by the end of May the stock of *Calanus* was very large along the slopes, where the sei-whale were caught.

In Icelandic waters whaling was carried on in the period from 1883 to 1915. The chart, Figure 45, illustrates the situation of the whaling stations,

which were built in Iceland during this period, and the depths of the sea bottom in the waters outside. The stations were situated in two groups, one at the north-western promontory, the other along the eastern coast of the island.

According to Risting (1922) one of the stations caught, in a period of twelve years, 2,171 whales, of which 1,296 were blue, 732 fin-backs, 17 sei-whales, 126 hump-backs.

By far the greatest importance was attached to the blue-whale. This whale appeared in Icelandic waters much earlier than in the waters off Finmarken. The first individuals appeared as early as the end of March or the first few days of April. The whalers thought that they came from the western Atlantic to the north-western promontory of the island.

During the summer blue-whales were caught along the whole northern coast. The distance from land at which they were caught varied in those years with the fluctuating distribution of the ice. In some years the ice approaches very near to the northern coast, in others it remains much farther away.

Fig. 45.

The experience of the whalers confirmed the hypothesis that most whales are to be found in the transition layers between the ice and the warmer layers, because these layers are the most prolific in "krill". No doubt *Thysanoessa inermis* was also present. Some blue-whales are, however, also stated to have been caught right among the ice. In the years when the stock of whales declined, the whaling boats had to go father and farther out. Some boats went as far as Jan Mayen, others far out in Denmark Strait, while boats from the east coast tried their luck in the waters towards the Faroes. When this industry was at its height in 1902 no fewer than 30 whaling vessels were employed. They caught over 1,300 whales, which produced some 40,000 barrels or nearly 7,000 tons of oil.

Whaling at the Faroe islands started in 1894, and it has been carried on there, more or less, ever since. At the height of the industry there were six stations. The finback is by far the most important species in the neighbourhood of the Faroes. At first some few blue-whales and hump-backs were caught. The sei-whale has been extremely irregular in its appearance: in some years there have

been great numbers, in others it has been almost absent. It will be sufficient here to give the following list of whales caught in the years 1922—1925, taken from records which Mr. ELLINGSEN, the director of Thorsvig Whaling Station, very kindly placed at our disposal.

Table 8.

Year	Finback	Sei	Blue	Sperm	Right whale	Hump-back	Total
1922.....	155	16	2	2	1	1	177
1923.....	97	2	2	..	..	1	102
1924.....	124	6	1	3	..	1	134
1925.....	137	..	1	..	..	3	141
	512	24	6	5	1	6	554

The chart, Fig. 40, shows the places where these whales were caught. It will be seen that almost all of them were caught at or near the edge of the bank and only very few on the bank proper.

The whaling seasons were as follows:—

in 1922 from 19th of May to 10th of September
in 1923 from 3rd of June to 25th of September
in 1924 from 11th of April to 11th of September
in 1925 from 19th of April to 12th of September.

This greatly resembles the dates for the summer fishing for fin-backs from the station at Aukra. The season is longer, however, than that at Aukra. It begins a little earlier and ends later — the middle of August being the end of the Aukra season.

Professor JOHANNES SCHMIDT courteously furnished the International Whaling Committee with some statistical material from the whaling off the Faroes in the years 1903 to 1916, during which period a considerable number of sei-whales were caught. From these statistics it appears that the maximum number of sei-whales was caught in the month of July; the whaling started in June and continued to a fair extent during the month of August.

For the Scottish Stations a valuable paper has recently been published by D'ARCY W. THOMPSON (1928). A series of charts illustrate the places of capture of the different species in different seasons. These charts prove, in the most striking way, to what a large extent the whales keep to the slopes of the coastal banks from the West of Scotland to the end of the North Sea bank (Tampen). This is especially true of the blue-whale and the fin-back, the sei-whales and the hump-

backs being sometimes caught on the bank, and the sperm whale at some distance outside.

The whaling season at the Scottish Stations lasts from April to October, May to August being the height of the season. To illustrate this we have compiled the following table from the data given by Professor D'Arcy Thompson:

Table 9.

	April	May	June	July	August	Sept.	Oct.
Nordcaper	..	3	45	20	1	..	..
Sperm-whale	1	4	20	16	31	3	..
Blue-whale.....	1	9	34	91	115	56	2
Finner.....	234	724	988	1247	1051	325	4
Sei-whale	11	219	910	446	117	17	1

We shall return to this table in the following chapter.

We have now reviewed the whaling, or rather some selected material from all the records of whaling along the slopes of the Norwegian Sea, hoping in a following chapter to be able to throw some light on the facts collected from these whaling operations. There is, however, one more area to be considered, an area which in many respects is of the greatest interest, namely the Norwegian Channel, running from the Norwegian Sea straight into Skager Rak. Whaling has for many years been tried along the North Sea slope, especially off the so-called Viking Bank, and of late years a whaling station has even been built at Blomvaag near Bergen on the Norwegian coast. The whaling grounds of this station are partly on the North Sea slope, partly along the North Sea Reef. It is very interesting that the capture of finbacks starts earlier and ends later there than at Aukra, the length of the season being very similar to that of the Faroe and Scottish Stations (see Fig. 37). It may safely be concluded, therefore, that the finback stays longer in these waters than at Aukra.

In some years finbacks are observed in the Skager Rak, mostly in connection with the immigration of herrings to these waters. Quite a number of whales have, during the last century, been reported as stranded in the Skager Rak, some on the west coast of Sweden, some in Danish or even in German waters. According to the information kindly sent us by Dr. O. Nybelin of the Swedish Hydrographical and Biological Commission these whales belonged to the following species: Sei-whale, Finback, Blue-whale and Humpback.

Chapter III.

Problems and Conclusions.

A. Plankton Communities.

Introductory Remarks.

"Le milieu externe".

The physiological idea which led to the study of the distribution of animals in relation to their environment (the "milieu externe" of CLAUDE BERNARD), revolutionized to a great extent, the old classification of marine animals based on their arctic, boreal or tropical "habitats". It soon became a recognized fact, that the distribution of the different animal communities in the ocean rarely coincides with what seem to be natural geographical areas.

Life History of animal Plankton.

Another extremely important change in the methodical aspect of marine biology has resulted from the recognition that the biological analysis does not end with the determination of species. The distribution of the individuals belonging to one and the same species may be very different at different stages in their development and also at different physiological periods of life. The spawning period has for instance been found to be connected with important geographical migrations (fishes) or vertical movements (plankton crustaceans). In some species the spawning or reproduction only takes place when the organisms can reach the sea bottom. It may therefore safely be postulated that all individuals belonging to such species, even if they are found drifting over the greatest ocean depths, were once born in a shallow sea and nearer to the coastal areas.

Of similar importance is the knowledge gained from an enormous number of cases, that certain stages, especially the ova and larvae, are subject to passive migrations under the influence of currents, and that the true pelagic species in all stages may be carried away into areas where they are quite unable to live at all.

Quantitative Methods.

A third and equally important new point of view was arrived at through the development of quantitative methods of catching, measuring, or counting the animal plankton in the sea. The quantitative study of the distribution of animal plankton was originally intended as a means of getting to understand the production of life in the sea, but it has also proved to be of great importance in the investigation of the geographical areas to which the different species are confined.

Present Material incomplete.

Very few species and very few geographical areas have, however, been studied in accordance with all these requirements. Our present knowledge of the distribution of most of the species is still based on very incomplete material. In the literature of the subject we find a great number of observations recording the occurrence of different species, but no information as to the quantitative distribution of the different stages or the conditions in which they occur.

In all attempts to arrive at a scientific knowledge of the distribution of marine animals we must, therefore, at present, admit the impossibility of giving other than tentative and preliminary working hypotheses, in the hope that these may prove to be of heuristic value. Limitation of the present Work.

With this reservation we will now consider in a more summary fashion the observations already described in the previous chapters, combining with them such information as we have found in the literature of this subject. We shall confine our attention throughout, however, to the plankton species which have been considered of most importance in the waters where whaling has taken place, in early or later years.

We propose first to review the plankton in the different characteristic areas of the sea and to analyse the conditions of life which have been found to exist in these areas.

1. Waters covered by floating Ice.

In his admirable Account of the Arctic regions William Scoresby made the first attempt to describe the community of animal species which "are always to be-seen wherever any tribe of whales" (i.e. the Greenland whales, *Balaena mysticetus* L.) "is found stationary and feeding". They consist of "various species of *actinae*, *cliones*, *sepiae*, *medusae*, *cancri* and *helices*". In the dead whales, however, "in the very few instances in which I have been enabled to open their stomachs, squillae or shrimps were the only substances discovered. In the mouth of a whale just killed, I once found a quantity of the same insect". William Scoresby.

"When the whale feeds, it swims with considerable velocity below the surface of the sea, with its jaws widely extended. A stream of water consequently enters its capacious mouth, and along with it, large quantities of water insects; the water escapes again at the sides; but the food is entangled and sifted, as it were, by the whalebone, which from its compact arrangement and the thick internal covering of hair, does not allow a particle the size of the smallest grain to escape".

Scoresby's Plate XVI enables us to identify the following species:—

The four ctenophores: *Beroe cucumis*, *Pleurobrachia pileus*, *Mertensia ovum* and *Bolina septentrionalis*.

The two pteropods: *Clione limacina* and *Limacina helicina*.

Of crustaceans there are figures which must be meant to represent: *Hymenodora glucialis* and *Calanus hyperboreus*.

The third, which from the point of view of the biology of the whale would be the most important, is, however, very difficult to identify (Plate XVI Fig. 14). It seems likely that it is meant to be *Themisto libellula*, which is very common in arctic waters. There would in this case be no figure of any Schizopod, which must be identical with the type of crustacea which Scoresby calls "shrimps".

In a special section (Vol. II pag. 207) Scoresby gives us his important

observations "on the Fishery of different Latitudes and Seasons, and under different circumstances of Ice, Wind and Weather".

The whaling season lasts from April to July. During this time Scoresby's principal field of operations was between the 78th and the 80th degrees of latitude along the ice off the east coast of Greenland. See Fig. 46.

"Grown fish are frequently found at the edge, or a little within the edge of the loose ice, in the 79th degree of north latitude, in the month of May; and small whales of different ages at fields, and sometimes in bays of the ice in the 80th degree.

Usually the fish are most plentiful in June; and on some occasions they are met with in every degree of latitude from 75° to 80°. In this month the large whales are found in every variety of situation; sometimes in open water, at others in the loose ice or at the edges of fields and floes, near the main impervious body of ice, extending towards the coast of West Greenland".

"There have been occasions in which whales have been seen and killed in the latitude of 71° or 72°, but the circumstances were peculiar, and the instances rare".

"In Baffin Bay, and in the inlets of West Greenland, the fishery is conducted under the most favourable circumstances. The water being shallow in many situations, the boats require only a small quantity of line, and the weather being warm, the sailors perform their occupations, if not with pleasure, at least with comfort to themselves".

We shall now proceed to consider the information available for an analysis of these conditions in the light of more precise observations.

German "Grönland-Expedition".

It may first of all be useful to consider the information collected by the German "Grönland-Expedition" of 1891 to 1893. This expedition adopted the very useful plan of selecting one of the northern fjords of the west coast of Greenland (the little Karajak fjord), near the large Umanak fjord and Disco Bay, and investigating this fjord all year round.

By proceeding in accordance with this plan the zoologist of the expedition, Ernst Vanhöffen, succeeded in obtaining the first accurate knowledge of the arctic marine plankton.

In the lists of plankton we find the following forms:

Medusae: *Codonium princeps* Haeckel, *Aglantha digitalis* Fabr., *Catablema campanula* Haeckel. These species occurred only as young individuals — in October as Sarsiae 3—4 millimetres in size. In summer large mature specimens were found in the wide outer fjords.

Ctenophors: *Beroe cucumis* Fabr., *Bolina septentrionalis* Mertens, *Mertensia ovum* Fabr., *Pleurobrachia pileus* Fabr. In the cold season they always kept below 50 metres, in August they appeared in the surface layers.

Siphonophores were only represented by *Diphyes arctica* Chun, in October at a depth of 180 m., in January at 75, and in March at 190 m.

Chaetognaths: *Krohnia hamata* Möbius, *Sagitta hexaptera* d'Orb, and *Sagitta bidentata* Möbius, in no season above 50 m.; in October observed at 90 and 225 m.

Pteropods: *Clione limacina* Phipps, and *Limacina helicina* Phipps, only young stages in deep water. *Clione* at 225 m., *Limacina* at 50 m.

Among the Schizopods the two species *Thysanoessa longicaudata* Kr. and *T. neglecta* Kr. were found in the little Karajak fjord.

The German expedition made no temperature observations in the fjord. The Danish fishery investigations in 1908 investigated the Umanak fjord, however, and Dr. J. N. Nielsen, the hydrographer of the expedition, writes (1909) that it is probable that

"all the year round there will be a rather deep surface layer of temperatures under 0° C. Along the bottom of this over 700 m. deep fjord there is, however, a layer several hundred metres deep, the temperature of which is about 1° C."

In the neighbouring Bay of Disco the "Michael Sars"-expedition of 1924 recorded the following characteristics of the water layers:

Table 10. "Michael Sars". Station 49. August 15th, 1924. 69°13′ N. Lat. 52°54′ W. Long.

Depth	Temperature	Salinity ‰	σ_t	O_2 cc.	M %	P_H
1.....	6.41	32.20	25.31	7.67	110	8.30
10.....	15	45	54	76	111	31
25.....	1.36	33.15	57	80	100	20
50.....	0.94	57	26.92	21	91	15
75.....	56	66	27.01	31	92	00
100.....	33	71	07	19	90	03
200.....	62	96	26	6.30	80	7.95
300.....	1.36	34.14	36	04	78	95
500.....	2.15	31	43	5.65	74	93
750.....	2.42	45	52	85	77	92

The "Michael Sars" Expedition in 1924.

In proceeding to consider the material from the "Michael Sars" expedition in the summer of 1924 it may be instructive to begin with an outline of the hydrographic situation in Davis Strait at that time.

As we have seen from Fig. 3 and 4, a strong south going current runs along the west side of the Strait, its temperature being not only below 0° but even below ÷ 1.5°. According to the view generally accepted by hydrographers this current, which carries polar water proper, is formed during winter somewhere or other

on the surface of the sea under the influence of severe frost in the air. Similar layers of water are also found in Davis Strait in the East Greenland polar current (see below), and have been described in accounts of the Canadian waters off New Foundland, Nova Scotia and in the Gulf of St. Lawrence (SANDSTRØM 1919).

These cold currents or layers of water everywhere resemble one another in biological respects as well, being so markedly deficient in life of all kinds that they might almost be termed "deserts". Very different from these are the layers of melted ice-water, which may have ice, ice-floes or icebergs floating in it, but may nevertheless be warmed by the sun in summer to a temperature several degrees above freezing point. This was the state of things that we found in the north going current off the west coast of Greenland, where a profusion of vegetable plankton develops during the summer months in a shallow surface-layer of water. VANHÖFFEN had previously noticed the same thing in the little Karajak fjord; and GRAN has subsequently described it in writing of the Gulf of St. Lawrence and Davis Strait (GRAN 1919 and this volume). This surface layer in the coast-current and the fjords of West Greenland forms a rich pasture for all kinds of larval forms of crustacea and fish.

A third type of water-layers is exemplified by the deep layers with positive temperatures, some being 1° C., others 2°, 3° or 4° C. Owing to their greater salinity these layers are always below the coastal currents, unless the latter go right down to the bottom, whether the coastal currents are pure polar water or warmed-up currents of melted ice-water. These deeper and warmer layers were themselves originally melted ice-water, increasingly mingled in course of time with salter and warmer Atlantic water. It is in these mixed layers that all the arctic forms, mentioned by VANHÖFFEN in connection with the Karajak fjord, congregate and breed, especially in winter and spring-time. Accordingly the early stages of jelly-fishes, siphonophores, pteropods and schizopods are present in them in winter, whereas in spring, when the surface becomes warm and plant-life develops, these early forms rise to the top in order to enjoy the spring vegetation there.

But these vertical migrations must not be regarded solely as adaptations to temperature. We must bear in mind the great importance of the sea-bottom itself. For jelly-fishes, pteropods, and even schizopods, the bottom is of the utmost importance as a condition of their life. There is a sea-bottom stage in the development of jelly-fishes and pteropods; and for a longer or shorter period of their lives the schizopods are detritus-eaters. It may perhaps even be said that they, like many of the dekapod crustacea (e.g. *Pandalus*), are denizens of the sea-bottom, which may at times, during the breeding season, "swarm" upwards to the surface of the sea.

The indication in Fig. 19 of the occurrence of the schizopods (and whales) in Davis Strait must be understood in the light of these general remarks. Thus it is not in the polar layers, but on the contrary in the arctic layers, that the

evolution of life takes place in all its profusion. The schizopods (of the *Thysanoessa* genus) and their early stages were found above the banks off West Greenland, which are covered by warm mixed layers of water, and that is why the whales frequented the same place. From SCORESBY's description of the Greenland whales caught in Davis Strait and Baffin Bay we may infer that the same state of things existed in regard to that species of whale. Thus Greenland whales were formerly killed on the eastern coastal banks, and not in the ice-cold western polar current.

The same thing is true of a number of the plankton forms which are regarded as especially arctic. We have already seen, for instance, that VANHÖFFEN found the larvae of *Clione limacina* in the deep layers of the fjord in winter, where the temperature of the water must have been at least 1° C. The "Michael Sars" found *Clione* larvae at Stations 31, 32 and 49 — all coastal stations near Greenland. Adult specimens were taken at Stations 40, 41, 58, 60 and 62, which were likewise near the coast of Greenland. But by way of exception it must be mentioned that a few specimens were also found in the cold current at Stations 42, 43 and 44. As regards crustaceans of any size caught in considerable numbers in this cold current there were only specimens of two kinds: *Parathemisto oblivia* and *Themisto libellula*. The only schizopods taken were two specimens of *Thysanopoda acutifrons* and one of *Mysis oculata*.

The "Belgica" Expedition.

The "Belgica" Expedition is of special interest, because it investigated precisely the part of the sea in which SCORESBY chiefly hunted the Greenland whale. This was in the great bay, or rather strait, between Spitzbergen on the east and the east coast of Greenland on the west, more especially between 75° and 80° N. Of special interest, too, in this connection, is the information received from Norwegian whalers to the effect that they have hunted the blue whale for a number of years in this area; and that prior to the great war, when engaged in this form of whaling, they came across Scotch whalers who were hunting the last of the Greenland whales in the drift-ice off the east coast of Greenland. Fig. 46 gives a rough chart of the conditions in these waters during the voyage of the "Belgica" as described by HELLAND-HANSEN and KOEFOED in their report on the expedition (1907).

This figure shows that along the whole extent of the south-going polar current there is a division between the unbroken ice and the open bank-ice, which floats in the layers of melted ice-water outside the polar current.

The expedition first steered northwards up the coast of Bear Island, then made its way along the west coast of Spitzbergen as far as the north coast. From thence it skirted the edge of the ice in a south-westerly direction all the way to the large bay shown on the chart in approximately 70° N.

All along the course of this voyage the hydrographical investigations revealed water-layers of the types already mentioned as existing in Davis Strait. The

expedition found that the polar current, with a temperature as low as $+1.7°$ C., ran under the unbroken ice near the coast of Greenland. In some places the current reached right down to the bottom, while in others it rested on a warmer inter-

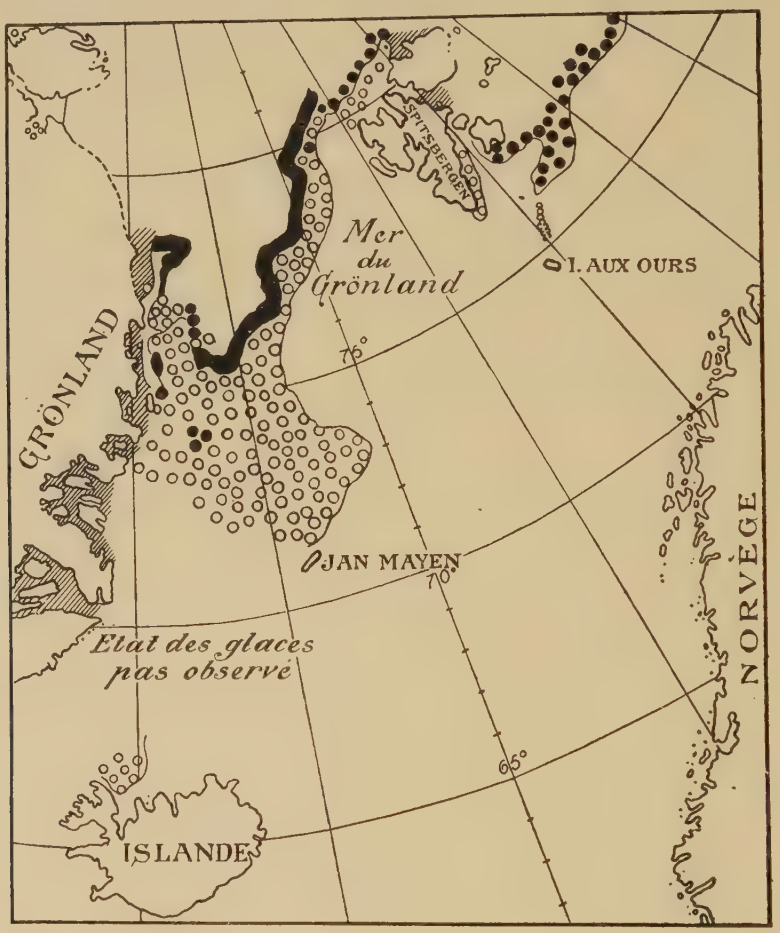


Fig. 46.

mediate layer, wedged in between the polar current and the deep bottom water which covers the entire floor of the Norwegian Sea, and is so closely akin to the polar current both in its origin and its characteristics.

In the intermediate layer which, following HELLAND-HANSEN and NANSEN, we will call the arctic layer of water to distinguish it from the polar layers, the temperature was found to be from 0° to 2° C. If the depth is not great this intermediate layer may go right down to the bottom of the East Greenland coastal bank, in which case it is, of course, no longer an intermediate but a bottom current.

To illustrate the various positions or configurations of these different layers in relation to one another we give a couple of examples.

Table 11. Station 21 A. 78°20′ N., 4°27′ W. at the Edge of the Ice.

Depth	Temperature	Salinity
0	+ 0.28	32.60
10	0.64	33.34
20	3.38	34.64
50	2.63	34.70
100	1.81	34.90
200	1.32	34.94
300	1.06	34.93
400	0.72	34.94
600	+ 0.04	34.93
800	+ 0.32	34.93

Three vertical hauls were taken at this station.

Between 10 metres and the surface the catch included, *inter alia*, *Calanus finmarchicus* and *hyperboreus* and larvae of *Themisto libellula.*

Between 50 and 20 metres there were *Krohnia hamata*, *Limacina helicina*, Nauplii of copepods, the two Calanids, and early stages of *Thysanoessa* and *Parathemisto oblivia.*

Between 300 and 100 metres there were, *inter alia*, *Aglantha digitalis*, *Krohnia hamata*, *Sagitta arctica*, *Limacina helicina* and *Thysanoessa longicaudata.*

Table 12. Station 31 A. 75°47′ N., 12°59′ W. Depth 350 m. on the East Greenland Bank.

Depth	Temperature	Salinity
0	+ 0.23	31.59
10	+ 0.58	31.78
20	+ 1.14	32.38
50	+ 1.75	33.08
100	+ 1.72	33.76
200	+ 1.00	34.48
250	+ 1.31	34.83
300	0.84	34.91
325	0.75	34.91

Here we have the polar current at the top and the arctic layer as the current at the bottom.

A haul in the uppermost 200 m. took the two Calanids, *Euchaeta glacialis*, *Metridia longa*, Nauplii of copepods, and early stages of *Themisto libellula* and *Parathemisto oblivia.*

A haul at a depth of between 300 and 230 m. took *Thysanoessa longicaudata.*

Here there really seem to have been fair numbers of early stages of the specially polar forms even in the "polar water". It is very interesting that "krill" was taken in the lowest layer near the bottom.

In going through the lists of plankton from this expedition we find the same species that we have mentioned in connection with Davis Strait (see, for example, the particulars taken from VANHÖFFEN). Among them are also the two pteropods *Clione limacina* and *Limacina helicina*, the former near the land and the latter as a rule near the edge of the ice. Early stages of both were taken in the neighbourhood of the coastal bank off East Greenland.

The number of Schizopods in the material collected by the expedition, which we have had an opportunity of studying, is very small. We suppose that this is due to the fact that the conditions under which the work was done did not admit of more effective catches. It can at any rate be said, however, that the two species *Thysanoessa inermis* and *Th. longicaudata* were greatly in a majority. They were usually taken in water with a positive temperature (1°—2° C.). At some stations early stages were found in water with a temperature of 2°—3° C. (St. 21 A).

The catches of *Meganyctiphanes norvegica*, taken at three stations (at two of which the temperature of the water was below 2° and 3° C.) are surprising. At one station (24 B) there were no hydrographical observations. This was the only place where the species was taken in large quantities.

The material contained an abundance of amphipods — especially the two species *Themisto libellula* and *Parathemisto oblivia.* At three stations the expedition took *Themisto bispinosa* or *compressa*; at the selfsame stations where *Meganyctiphanes* was taken.

For the rest, we shall confine ourselves to quoting the authors' interesting statement that the fauna in this warmer intermediate layer bear a remarkable resemblance to the animal life of the Norwegian Sea.

"The plankton in the warm intermediate layer of the Greenland Sea forms as it were an extension of the fauna of the Norwegian Sea."

Here again we see that it was once possible to catch large numbers of the Greenland whale in the fjords of Spitzbergen, where there is arctic water with positive temperatures during the summer. And this agrees with the fact previously mentioned, that the Greenland whale was caught in old days on the east and not on the west side of Davis Strait.

From outside the above-mentioned two areas — Davis Strait and the field worked by the "Belgica" Expedition — we have also a considerable number of observations, although they are of a more scattered nature.

Thus Nansen (1925) has published his observations made at the beginning of the 'eighties on a voyage during which he explored the margin of the ice from almost 80° N. down to Denmark Strait in the south. Fridtjof Nansen.

It appears from Nansen's observations that three regions, in particular, along the edge of the ice, afford the necessary conditions for an abundant fauna, these being Scoresby's whaling grounds, which have just been described, the Jan Mayen grounds south and north of Jan Mayen, where the young of the Greenland seal and Hooded seal are hunted, and lastly Davis Strait.

Fig. 47. Old Dutch Whaling in Spitzbergen Fjord. After "Der Walvischfangst". Amsterdam 1784.

Along the ice, especially in these regions, the seals everywhere kept to the drift-ice near the margin of the ice, where there is enough open water between the floes. The young seals live

"at first mainly on small crustaceans (including Schizopods), of which there are great numbers in the upper layers of the sea, and I have found the stomachs of young seals of this age packed with them".

"They also eat whale-food, pteropods (*Clione limacina* and other small creatures which swim about in the sea); and where these are present in large quantities the seals are chock-full of them". But farther within the ice-bound region "the polar sea layers of water are practically a desert".

"It is probable that in the neighbourhood of the breeding grounds it is especially easy for the young seals to find large quantities of pelagic crustaceans,

and other small creatures that they require during the important time after they first enter the water and begin to feed themselves. It is a striking fact that it is precisely in the spring, in April and May, that there are large quantities of these creatures, and of the small plants (algae) upon which they exist, in the upper layers of water near the seal's breeding grounds in the Jan Mayen sea and east of Newfoundland, and also in the White Sea".

It seems to us to be an obvious inference that all these breeding places have one common feature: they are situated above typically coastal banks. This is true of the three above mentioned areas outside the coast of East Greenland, and likewise of the Newfoundland and White Sea breeding grounds.

The Barents Sea.

We have a good many observations from the margin of the ice in the Barents Sea, where the plankton animals follow the rhythmical movements of the ice to the north-east or south-west, according to the time of year. Our information on this point is chiefly derived from the whalers and sealers. As regards the Bear Island fishing ground, INGEBRIGTSEN's paper (in the present volume) shows how the whales feasted on "krill" in the sea to the west of Bear Island, just outside the ice-cold layers of water, when the summer temperature was 3° C.

In the Barents Sea the ice in summer bends in a great curve towards Novaya Zemlya. The Sealers' logbooks, from which WOLLEBÆK has collected useful information (1907), tell us that there is an abundance of whale-food, *Clione* and "krill" (*Thysanoessa inermis*), all along the margin of the ice, and that "lodde" (Caplin) and whales (Fin-backs) have been observed far to the east and in the north at midsummer.

Newfoundland

The "Michael Sars" expedition in 1910 collected interesting material from Newfoundland, of which we shall have more to say later on. For the present it will suffice to state that BIGELOW mentions finding, off the coasts of Newfoundland and Labrador in 1900, *Clione* and other arctic forms among the ice-floes on the Newfoundland Grand Banks.

2. Atlantic Waters.

Hydrography

We do not propose to review at any length the very full literature which is now available for the study of the "Atlantic" layers of water south and north of the Norwegian Sea.

We will therefore content ourselves with taking as our point of departure the chart which HELLAND-HANSEN prepared for his report in "The Depths of the Ocean", showing that a strong current runs into the Norwegian Sea from the Atlantic. (See Fig. 48).

We will adopt the hypothesis — which we are aware is only correct up to a certain point — that the particles of water in this current remain unmixed with other layers of water so long as they keep to their main direction, but that,

Fig. 48. The Currents of the Norwegian Sea. Drawn by B. Helland-Hansen. "Depths of the Ocean".

when they turn east or west and adopt a rotatory movement, they become mixed with water from other sources, on the west more especially with the Polar current, and on the east with coastal water from the rivers of Northern Europe.

Of course, we are fully aware that no current ever moves in an absolutely straight line — the tides alone are sufficient to render this impossible — and that the hydrographical data have in consequence assumed such a degree of complexity that no comprehensive and clear survey of the conditions can as yet be said to

exist. But for the special purpose we have in view we consider ourselves justified in adopting a broadly schematic point of view and ignoring these complications, as has been done in the figure reproduced here.

Atlantic Immigrants.

The immigrants accompanying this current from the Atlantic Ocean to the Norwegian Sea may be more or less schematically divided into several different groups.

Summer Guests.

Thus we can speak of active swimmers, such as tunny, various sharks, and the sperm-whale, which appear as summer guests on short visits to the Norwegian Sea, without staying permanently or breeding there. If they are not caught by fishermen or whalers they emigrate again to the Atlantic in the autumn.

Deep-Sea Forms.

Another large group of "pelagic" species of fishes lives in the Atlantic, in layers of water of varying depths. When such water comes in contact with the Wyville Thomson ridge it is lifted up above the specifically heavier layers of the Norwegian Sea, and the animal life in it is brought to the surface, where these creatures die and are washed up on the coast of Norway, especially during the autumn and winter months.

The "Michael Sars" expedition in 1910 studied the horizontal and vertical distribution of these forms in the North Atlantic, and Robert Collett (1905) and O. Nordgaard (1910) collected all the facts which have become available from time to time concerning the creatures thus thrown up on the coast. All these particulars have been compared and discussed in "The Depths of the Ocean", pp. 641—644, so we consider it unnecessary to repeat the same information here; but we would refer any reader who wishes to know more about this interesting problem to the volume in question.

The point that we desire to emphasize here is that these deep-water forms, coming from warm intermediate layers in the Atlantic, are raised to the surface, where they perish. They cannot adapt themselves to the Norwegian Sea and are borne along by the current to places where they cannot live.

Settlers.

A third large group embraces all the forms which have either come themselves, or have been brought several generations ago, from the Atlantic to the Norwegian Sea, and have adapted themselves to the conditions there. One special and peculiar kind of adaption is met with in the case of certain fishes which visit the Norwegian Sea or the North Sea in summer and breed there, but disappear again in the autumn. Among these are, for instance, the mackerel and the hake. They may be said to live in the Norwegian Sea in summer and during their early stages.

Quite a number of Atlantic species, however, have settled down in the Norwegian Sea for life. In "The Depths of the Ocean" Hjort, following G. O. Sars, compiled statistics of the numbers per cent. of Molluscs which live on the coast of Norway but are also found in more southern waters.

It may be useful to quote the following paragraphs: "Of the 174 species

of lamellibranchs living on the coast of "Arctic Norway" no less than 128 or 74 per cent. were known also from Great Britain; 119 or 70 per cent. from the Mediterranean and 56 or 32 per cent. from boreal North America.

Of 366 species of gasteropods found in Norway 225 or 62 per cent. were also known from Great Britain; 133 or 36 per cent. from the Mediterranean and 77 or 23 per cent. from the coasts of boreal North America".

"Examining the conditions in various parts of the coast of Norway we see that the Mediterranean species rapidly decrease in number as we go north from western Norway, for instance from the latitude of Bergen towards the North Cape. While 119 lamellibranchs and 133 gasteropods are common to the Mediterranean and Southern Norway, Northern Norway and the Mediterranean have only 49 lamellibranchs (28 per cent.) and 35 gasteropods (10 per cent.) in common."

This information is of fundamental importance for understanding the life history of the species with which we are chiefly concerned here, namely the *Meganyctiphanes norvegica.*

Meganyctiphanes norvegica.

This species is, geographically speaking, very widely distributed. JOHANNES SCHMIDT took it at a large number of his stations during a winter cruise in the Mediterranean. (See JESPERSEN 1923.) As we have seen in Chapter II, this species plays the chief part along all slopes of the south-eastern portion of the Norwegian Sea, round the Faroe Islands, Shetland, "Tampen", the Norwegian Channel and off Møre. In the previous chapter we tried to prove the contention that this species, like all the other Schizopods, should be regarded as a denizen of the bottom; in other words it lives for the greater part of the year on detritus and sinking organisms along the bottom, as well as *Pandalus* and other crustaceans. On one occasion in the 'nineties HJORT saw the prawn-fishers suddenly catch tons of this species in their trawls; and the biological station at Drøbak (Oslo fjord) has often taken them in nets dragged just above the bottom, when none could be caught in the water higher up.

The investigations off the coast of Møre have shown that *Meganyctiphanes* has a highly important connection with the appearance of the fin-back whales in summer. But for the fin-backs it is necessary that the "krill" rise to the upper layers of water. Now the researches off Møre have convinced us that Schizopods only "swarm" during spawning time, and that this is an important point of departure in studying the appearance both of the "krill" and the whales.

Meganyctiphanes spawns, at any rate mainly, in the south-eastern part of the Norwegian Sea in summer.

So far we can judge from SCHMIDT's catches, the spawning time in the Mediterranean must be in winter. The catch of whales off Gibraltar was always greatest in winter-time. If this is correct the spawning time would probably occur when the temperatures were more or less the same.

North of Møre the numbers of *Meganyctiphanes* evidently decrease very

much. We have already seen that fair quantities are taken as far up as Lofoten. But in the Barents Sea and onwards towards Greenland there only seem to be scattered individuals doomed to destruction.

Evidently the state of affairs is different in the outlying layers west of the Atlantic Ocean Current. In this connection we greatly regret that we have only had a small motor-vessel which is very unserviceable for long expeditions, such as are necessary for systematic investigations of a number of sections across the Atlantic Ocean Current. However, we possess a little material from the cruises of whalers and of the Swedish research-steamer "Skagerak", which just got as far west as the edge of the Atlantic Ocean Current.

It appears that there are early stages of *Meganyctiphanes* in these western waters, and that they are found later in the year than similar stages on the Norwegian side. Quantities of larvae have been found in August, at a time when they had already become rather scarce in the eastern waters. This agrees with the results of Ruud's study of *Calanus finmarchicus*. The latter species has also either a later spawning time, or a more prolonged one, on the west side of the Atlantic Ocean Current; a point of vital importance in our endeavour to understand the economy of the Norwegian Sea.

All researches of recent years into the development and subsequent dwindling away again of the plankton have sought to relate these phenomena to the nutrient potentialities of the sea-water itself. Can these potentialities only be exploited later in the year in those western waters or are they so rich that they last much longer? The solution of this problem would be a valuable piece of work, calling for fuller and more comprehensive investigations than those which we have been in a position to make.

As regards the *Meganyctiphanes* there are two possibilities. On the one hand the larvae may come from a spawning ground in the Faroe-Iceland region. On the other hand there is the hypothesis, put forward many years ago by Hjort (1901), that a "Sprungschicht", or increase in specific weight, takes place in the transitional layers between the Atlantic water and the mixed layers to the west, with the result that a boundary-layer may serve the same purpose for a pelagic organism as the sea bottom does, by stopping sinking organisms on their way down, and thus collecting a layer of nutritive matter in the very middle of the water.

Thysanoessa longicaudata.

In the long sections subjected to examination a form was found in the genuinely Atlantic water, which perhaps leads the most truly oceanic existence, and is the least dependent upon the sea bottom of all the northern Schizopods. This form is *Thysanoessa longicaudata*. It spawns early in summer, and its larvae have been found in the whole section through the Atlantic Ocean Current.

Gulf of Maine.

These species also play the chief part on the west side of the North Atlantic. From his researches in the Gulf of Maine H. B. Bigelow concludes that *Meganyctiphanes* spawns there in summer, "which fits in with the season of abundance

of euphausiid larvae and points to the north-eastern part of the gulf where this shrimp is so abundant, as its chief spawning ground". "Our failure to find it at any of our February-May stations over the continental slope abreast of the gulf suggests that it vanishes similarly from this portion of its range in late winter and spring."

3. The western mixed Layers.

Hydrography.

The two great vortices of current to be seen on the chart (Fig. 48), west of the Atlantic Ocean Current, transport, according to HELLAND-HANSEN and NANSEN, "arctic water".

"What we call arctic water is formed in the Norwegian Sea (Greenland Sea and Iceland Sea), and is an intermixture of originally Atlantic water with originally Polar water, and also with water which has been cooled during the winter in the Norwegian Sea, and which, during the summer may have been diluted by the water of the melting ice. Arctic water forms more or less the central waters, and we find Arctic water in the eastern boundary areas of the East Greenland Polar Current; it is also a similar kind of water which forms the intermediate warmer layer underlying this current. The Arctic water has temperatures between 0° and 2° C., and salinities from 34.6 to 34.9 $^0/_{00}$."

It is perfectly true that this short definition provides a very clear picture of the origin and character of the ocean water in the two great vortices. Nevertheless we must remember that on the east, towards the waters of the Atlantic Ocean, there are not clear-cut boundaries between layers of Arctic and Atlantic water, but sharply defined transitional layers with temperatures between 4° and 6° C. In the deep water, more especially, we find these transitional layers stretching far to the east, hollowing out, as it were, the deepest part of the Atlantic Ocean Current.

Accordingly there may be a certain amount of justification for dividing the mixed layers between the Polar and the Atlantic water into two groups: one with boreal temperatures (3°—6° C.), and the other, more arctic group, with temperatures from 0° to 2° C. The latter layers are, as HELLAND-HANSEN and NANSEN expressly state in the passage quoted above, identical with the intermediate layers which play such an important part in the sea beneath the floating polar ice, and have so frequently been mentioned here in connection with the "Belgica" Expedition. It was only natural that DAMAS and KOFOED should notice, from a biological point of view, the connection between this intermediate layer and the water of the Norwegian Sea. The plankton in the intermediate layer is a direct continuation of the Norwegian Sea plankton — or more properly the plankton of the western mixed layers.

Unfortunately we must hasten to add that these mixed layers have not been studied with the thoroughness that we could wish, especially in their quanti-

tative aspects. Enough observations have been made on the various cruises of the "Michael Sars" to determine the composition of the more important species of plankton, but all the highly important problems of development and quantitative observations have been entirely neglected.

In particular we may mention that the "Michael Sars", on her first voyage in August 1910 between Møre and Iceland, frequently took, at a number of stations west of the Atlantic Ocean water, forms such as *Aglantha digitalis*, *Calanus hyperboreus*, *Euchaeta norvegica*, *Parathemisto oblivia* and *Thysanoessa inermis*; and that the last-named form was found in patches consisting of great masses like blood-red blotches on the sea, and also in the stomachs of herrings, saithe and sea-birds of various kinds (Stations 9, 10 and 11, and right up to Jan Mayen).

In the absence of any quantitative estimate of the enormous importance of the Schizopods in these waters — such as methodical investigations there would undoubtedly have afforded — we hold that we have a right to draw certain conclusions from the presence of creatures which would be unlikely to appear in this western portion of the sea unless Schizopods (above all *Thysanoessa inermis*, but, farther east towards the Atlantic Ocean water certainly *Meganyctiphanes norvegica* as well) were present too in vast quantities.

The creatures in question are, first and foremost, the herring; next, the squid *Gonatus fabricii*, which would not be likely to appear in the Norwegian Sea unless there were plenty of Schizopods and herrings. And then, closely connected with these fishes, the bottle-nose (*Hyperoodon rostratus*).

The Bottle-nose Whale.

Various expeditions to this western area, called by fishermen the "Bottle-nose grounds", have collected from year to year particulars of the exact hunting grounds where the bottle-nose is caught, and of the contents of its stomach. This always contains either herring or *Gonatus fabricii*, both of which must abound in enormous numbers in this area; and seeing that both owe their existence in these waters directly or indirectly to the Schizopods, a striking picture is revealed of the immense riches stored in that ocean region. During the cruises of the "Michael Sars" herring nets were put out on various occasions as a more direct means of ascertaining the presence of herring and to get samples of the species.

We will return to the latter question later on. Meanwhile the attention of the reader may be called to Fig. 49, in which we have tried to indicate the grounds where herring or bottle-nose have been caught, on the hydrographical chart of this area drawn by Helland-Hansen for "The Depths of the Ocean". It will be seen from the chart that catches have been made in the transitional layers between the Atlantic water and the Arctic layers, and beyond them in the Arctic layers themselves.

The first researches in the "Michael Sars" gave us, on the whole, a strong impression that a definite connection exists between the arctic layers of water, as defined above, and certain typically arctic forms of animal life. But it has not

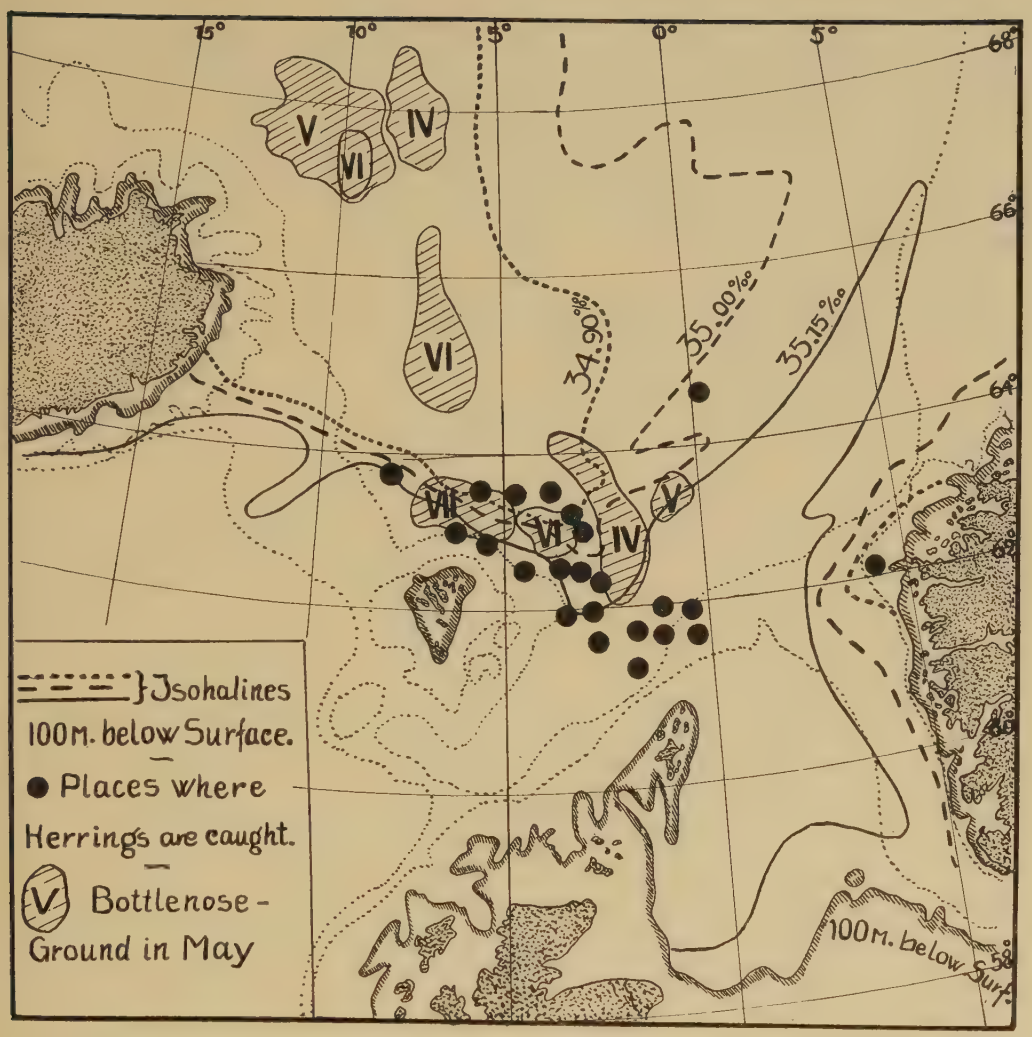


Fig. 49.

always been easy to trace any clear and complete regularity in the distribution of these forms, in conformity with the definite factors of salinity and temperature. As an interesting example of such difficulties we will consider the occurrence of the "whale-food" *Clione limacina* in different parts of the area.

Clione limacina.

In connection with his first researches Hjort (1902) published a chart showing the distribution of *Clione* at different times in the northern part of the Norwegian Sea. We would refer the reader to Fig. 50, which gives the nearest distances from Norway at which *Clione* was observed on two different voyages. Hjort regarded *Clione* as one of the most typical representatives of the forms

which swim wherever they like. "Whenever they are found it is a sure sign that there is an admixture of arctic water; but this admixture may be very slight, these organisms being the only certain means by which we can prove it."

But this seems to have been disproved since then by the Danish investigations to the south of Iceland. In these researches south of Iceland and above the ridge between the Faroes and Iceland early stages of *Clione limacina* were found in layers of water which, both as to salinity and temperature, were quite

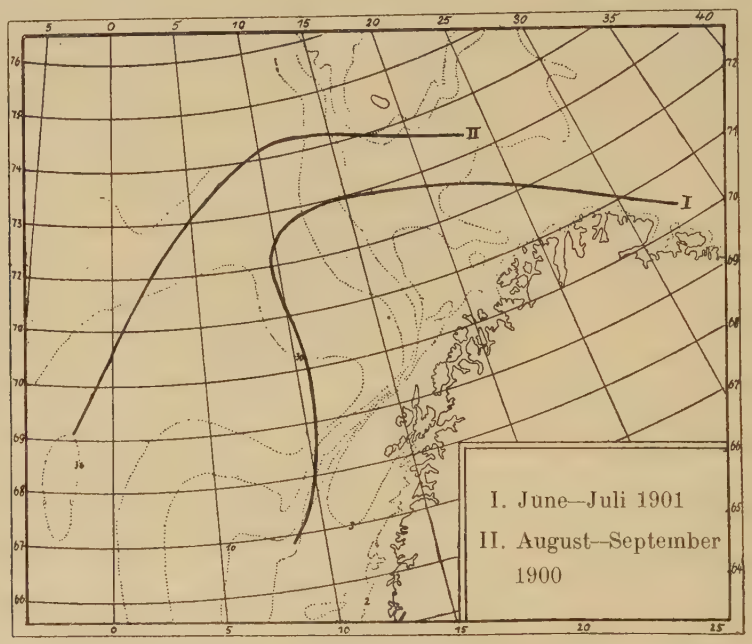


Fig. 50. Nearest distances in which *Clione* was observed.

"Atlantic". Moreover the "Michael Sars" found early stages of *Clione* in 1924 on St. 22 south of the Iceland-Faroe ridge. See, for instance, PAULSEN (1909).

Here we are confronted by a marked divergence in the distribution of two separate groups of this important organism. On the one hand there are the numerous arctic localities where it has been found by VANHÖFFEN and the "Michael Sars" off West Greenland, and by the "Belgica" Expedition off East Greenland. On the other hand, there are the Atlantic finds right down in the area south of the Norwegian Sea.

Not unnaturally, therefore, there has been a good deal of controversy about the grouping of this form; and attempts have been made to find an explanation which will reconcile the contradictory facts, in as much as these facts seem to undermine the fundamental hypothesis upon which such biological studies as

these are based, viz. that there is a definite relation between the occurrence of the various species and their environment. Damas and Kofoed seem to have felt this strongly, for they suggest in general terms that *Clione* may go deeper in southern than in northern waters. At that time, however, there were no facts upon which to base such a hypothesis. We will now take up the problem afresh, and endeavour to make a contribution of our own towards its solution.

In the first place we will recall the facts which serve as our point of departure:—

1) *Clione* is observed to breed in arctic layers of water, with a temperature between 0° and 2° C.; at the bottom of coastal banks whence the larvae are spread

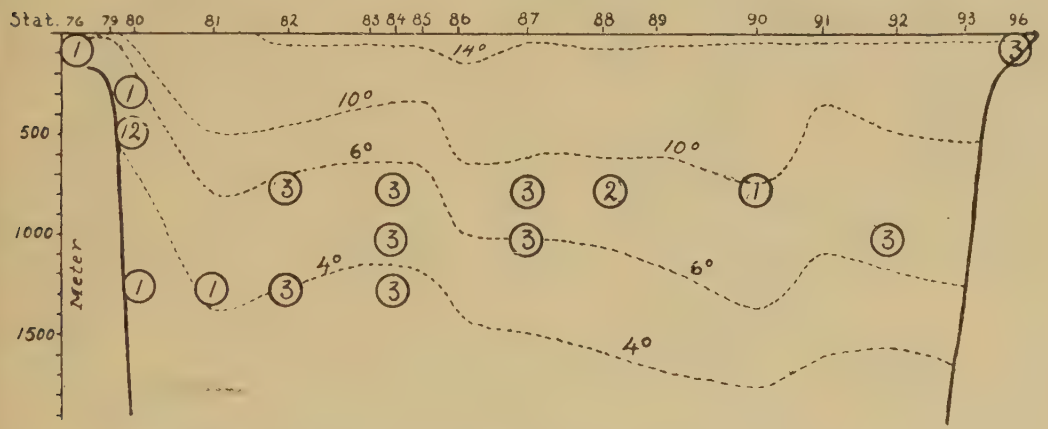


Fig. 51. Vertical distribution of *Clione limacina* between Newfoundland and Ireland. The encircled figures denote the number of individuals captured.

abroad by the sea currents which they encounter. This has been found to be the case off Spitzbergen, and in fjords and on coast-banks both on the east and the west of Greenland.

2) During the cruise of the "Michael Sars" in the Atlantic in 1910 the Newfoundland Banks were investigated, and all the species described above as arctic, including *Clione*, were found near the slopes of the banks in temperatures of rather more than 2° C.

3) During the cruise of the same ship from Newfoundland Bank to Glasgow, across the northern part of the Atlantic, hauls were made with tow-nets at all depths, and *Clione limacina* was found to be present in a layer extending from 700 or 800 m. to 1500 m., composed of mixed layers of Atlantic and Polar water of lower temperatures. See Fig. 51.

4) These layers of water sink, as we know from the reports of hydrographers, from the west Atlantic coastal banks, especially those of Newfoundland, in the form of an undercurrent below the warmer Atlantic layers. With these sinking

layers go numbers of the arctic forms otherwise found on the top or the slope of the Newfoundland Bank.

5) These sinking layers spread out like a fan. Some of the water goes southward, and can be identified both by its physical and biological features as far south as the Sargasso Sea, where such typical forms as *Euchaeta* are found in the deep water (NORDGAARD 1916). But some of the water goes eastward, and is

Fig. 52. Salinities and Temperatures in the North Atlantic at a Depth of 500 Fathoms in the Summer 1910. From HELLAND-HANSEN in the "Depths of the Ocean".

borne along to the area where the transition to the Norwegian Sea begins, i.e. the upward slope leading to the Iceland-Faroe-Shetland ridge.

In Fig. 52 we reproduce a chart of this region at a depth of 500 fathoms (about 900 metres). This chart shows the huge tongue of water, with a salinity of less than 34.9 $^0/_{00}$, which here curves eastward. The conditions have not been established with certainty, as the observations have been too few, but if we compare Fig. 51 and Fig. 52 we can easily see how *Clione* could be carried by the arctic or almost arctic layers from the Newfoundland Bank to the slope of the bank mentioned above.

6) We therefore advance the hypothesis that the individuals of the species *Clione limacina*, which assemble in the deep water in this north-western corner

of the Atlantic when they arrive at the slope leading to the southern threshold of the Norwegian Sea, spawn at great depths, possibly as far down as 1000 m.; after which the larvae ascend to the surface of the sea.

In selecting *Clione limacina* as an example upon which to base the above hypothesis, we have done so, not because it stands in a category by itself, but on the contrary because it represents a characteristic group of organisms. We will give a few particulars concerning some of these.

Schizopods in the deep water of the Atlantic.

During the cruise of the "Michael Sars" in 1924 we found several forms in the upper layers on the coastal banks off West Greenland, which had only been found in deep layers of water in the Atlantic Ocean proper. For instance the Schizopod *Thysanoessa longicaudata* was present, as stated in Chapter I, in the upper layers of water near West Greenland, but only below 500 m. at the stations in the Atlantic on the return voyage to the Faroes.

Larvae of Gonatus fabricii.

Specially interesting is the distribution of *Gonatus fabricii*, the squid which plays such a part in the mixed layers and in the economy of the bottle-nose whaling grounds. On the voyage to West Greenland a number of larvae were caught, which have been studied by Dr. Hjalmar Broch, from whom we have received the information arranged in the subjoined table. It will be seen that there were some rather small larvae, and the youngest of these seem to have been caught at the

Table 13. *Gonatus Fabricii* (Lichtenstein 1818).

Mantle length in mm.	St. 40. 200 m. W.	St. 41		St. 58. 1000 m. W.	St. 59. From Stomach of Cod	St. 60				St. 62	
		200 m. W.	600 m. W.			100—50 m.	100 m. W.	200 and 300 m. W.	400 m. W.	100 m. W.	300 m. W.
39—41											
36—38									●		●
33—35					●				●		
30—32			●					●●	●●		●●
27—29									●●		●●
24—26	●	●	●					●	●●●●●		●
21—23			●●●				●	●●●●●	●●		●
18—20	●					●		●●●	●		
15—17				●				●		●	

least depths. All the stations where these larvae were taken were on the slopes of the coastal banks (St. 40, 41, 58, 59, 60, 61), and they were found especially in the south-western area, not in Baffin Bay.

With this we can now compare the very interesting fact that the "Michael Sars", on the voyage from Newfoundland to Ireland in 1910, found not only *Clione limacina* but larvae of *Gonatus fabricii*, everywhere in precisely similar conditions.

The squid from the "Michael Sars" cruise were dealt with by Carl Chun (1913) who observes in his report that "some specimens were taken in plankton nets at the stations recorded below, including young animals which with a mantle length of 17 to 18 mm. have not yet transformed their middle suckers into hooks."

The stations at which these specimens were caught were:

Station 70 in a haul with 200 metres of wire
— 80 - - — — 2000 — - —
— 81 - - — — 3000 — - —
— 94 - - — — 2000 — - —

whereas Station 70 was situated on the top of the Newfoundland Bank, the other stations were out in the deep-sea waters of the Atlantic, just as we saw in the case of *Clione limacina*.

Larvae of Species of Fish living deep down.

When the larval stages of *Clione limacina* were found by the Danish research expeditions, they were discovered in company with a number of interesting examples of fish that live on the deep-sea bottom, especially *Molva byrkelange*. In his treatise on the distribution of the larvae of the cod species Johannes Schmidt (1909) writes:—

"The small fry (of *Molva byrkelange*) were constantly accompanied by numerous pelagic fry of *Sebastes marinus*, which were found both to the south and west of Iceland in enormous quantities over deep water, and also by the small fry of *Gadus poutassou* and *Scopelini*, in addition to numerous oceanic plankton forms, as for example *Clione limacina*, *Cleodora pyramidata*, *Diphyes*, *Mysophora* etc. . . ."

Fig. 53 reproduces a chart which the International Committee A published in its report on the spawning grounds of the Gadids (1909). This figure shows the spawning grounds of the three species of ling, including that of *Molva byrkelange*, which will be noticed on the slope of the plinth upon which Iceland, the Faroes, and the whole threshold of the Norwegian Sea are situated.

Immigrants from the Atlantic.

The young larvae of these forms rise in due course to the surface of the sea and are then carried into the Norwegian Sea, where they are drawn into the movement of its currents. In this way the bottle-nose grounds are supplied with quantities of the larvae of *Gonatus fabricii*, and the deep banks with their fishes.

Although these forms apparently come in from Atlantic water, they are

Fig. 53. Spawning regions of the three species of the genus *Molva*. Horizontal lines and the darkened portions denote *Molva molva*; vertical lines *Molva byrkelange*, and the dots *Molva elongata*.

spawned in the layers below it, where the salinity is lower owing to the intermixture of Atlantic water and what was originally Polar water, and where the temperatures are nearly arctic, or at any rate what we have tentatively called "boreal".

These facts support the conclusion that there is a biological distinction between Atlantic water proper and these layers mixed with ice-water. We may therefore assume as a general proposition that the western mixed layers under consideration here must be regarded as a separate area of the sea. Perhaps as good

a term for it as any would be the Bottle-nose Grounds. And we may further assume that it has its own special stock of organisms.

Copepods.

Ruud's studies with regard to the breeding habits of the copepods, especially *Calanus finmarchicus*, in the Norwegian coastal waters, indicate likewise that there is a difference between the bottle-nose grounds and the coastal waters of the Norwegian Sea. At any rate it will serve as the best working hypothesis for further investigations if we presuppose that the bottle-nose grounds produce their own Calanids and Schizopods, possibly with specially characteristic spawning grounds and regular drifting routes for the larvae in the currents of the sea. We think it most likely that the spawning grounds will be found chiefly in the transitional layers nearest to the Atlantic Ocean water; and that the larvae will drift with the vortical current which is also indicated on the chart Fig. 48. But the full demonstration and description of all this must be left to the quantitative investigations which will doubtless be undertaken in time to come in this important area of the sea.

4. The Norwegian coastal Waters.

Hydrography.

The coastal water outside the coast of Norway passes into the current which, broadly speaking, forms a continuous system from the Baltic, through Skager Rak, and along the Norwegian coast to the Murman Coast.

The transition from this coast-current to the Atlantic Ocean Current, which runs in practically the same direction, is rather abrupt. As the boundary we may set a salinity of 35 ‰.

It has been found that the salinity of the coastal current increases as it goes from south to north, because there is a considerable amount of admixture with the salter water of the Atlantic. Outside the Murman Coast the salinity is uniform in May, being between 34 and 35 ‰.

While the salinity increases in the passage northward, the temperature falls. This will be seen from the table below, compiled from data in the treatise by Helland-Hansen and Nansen.

Table 14.

Depth	Skager Rak	Sognefjord	Möre	Lofoten	Murman
at 20 metres.....	5.93°	6.86°	8.94°	5.61°	2.75°
at 100 metres.....	4.94°	6.61°	7.10°	6.51°	2.63°

The table shows that in the month of May — after the cold of winter is past, but before the summer heat sets in — the temperature is fairly uniform,

with only a slight decrease up to Lofoten, but with a marked decrease after that, as we proceed eastward to Finmark and the Murman Coast.

In winter the temperature is very low in Skager Rak, where ice may cover large areas of the sea in some years. This winter coldness continues there, far on into the summer, as an intermediate minimum temperature after the upper layers of the sea have become very warm.

Compared with this the temperature all along the west coast of Norway is nearly uniform, being higher in winter and lower in summer than that of Skager Rak.

Finmark never attains the temperature characteristic of the west coast. There is a very noticeable drop of several degrees from the point where the coast bends eastward.

The biology of the coastal waters of Norway has been the subject of repeated investigations during the last fifty years, from the point of view of its fauna, its historical evolution, and its biology in the general sense of that term. In this chapter, we must first emphasize the fact that the quantitative investigations, reported on by H. H. Gran and J. T. Ruud elsewhere in this volume, have proved at last that the coastal waters must be regarded as separate regions, characterized by the dependence of their production upon the season and the chemical conditions of life present in the coastal current.

Copepods.

Ruud has shown that *Calanus finmarchicus*, the most important of all the copepods, spawns on the coastal banks and their slopes, and that the stock of copepods has a source of its own from which it is replenished by immigrants from the coastal current farther to the south, and not from the water on the other side of the Atlantic Ocean Current. It has been found that the appearance of the sei-whale on the Møre bank coincides with the time when the stock of copepods is at its height, and that, roughly, these coinciding factors vary together from one year to another.

Spawning times and spawning grounds of the Boreal Species.

A characteristic of the coastal current is the regular recurrence of a definite spawning time for the chief species found in it. A number of the chief fishes, especially the cod and the herring, and also the forms which pass one stage of their existence at the bottom, e.g. the jelly-fishes, spawn in the spring months in temperatures approximating to the interval which was termed arctic in the previous section, namely between 0° and 2°. This arctic interval does not, however, seem to be an optimum for the fauna of the coastal current; that would seem to be nearer 4°. In summer these coastal forms live in considerably higher temperatures. In "The Depths of the Ocean" Hjort has shown that the southern limit of these forms, for which we suggest the common title of "boreal" forms, is near the course of the 10°-isotherms on either side of the Atlantic Ocean. See Fig. 54, which shows the region of the "boreal temperatures" at a depth of 100 metres in the North Atlantic. South of 10° C. we find an entirely different fauna, both as regards fishes

and evertebrates, inhabiting a wide belt stretching from the Bay of Biscay far down along North Africa till it reaches the tropical region.

Early Stages adrift.

G. O. Sars showed in the 'sixties that the earliest stages of the young of the various species of cod may be found drifting in the sea in a kind of symbiosis with the stinging jelly-fish *Cyanea capillata*, the earliest pelagic stages

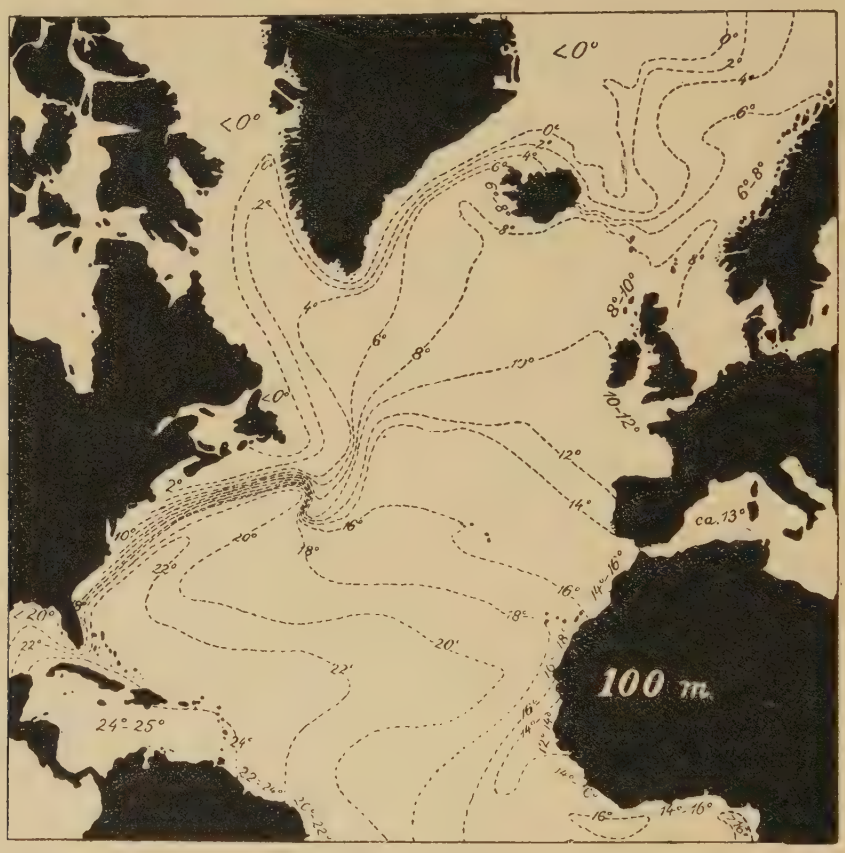


Fig. 54. Distribution of temperatures in the North Atlantic at a Depth of 100 metres. Drawn by Helland-Hansen, "Depths of the Ocean".

of which are likewise found on the coastal banks. Consequently the sea around the coast swarms in the early summer with all these forms, floating out to sea under the influence of the coastal current. On the first summer cruise of the "Michael Sars" in the Norwegian Sea in 1900 this procession of drifting forms was encountered far out in the ocean — as far to the west, in fact, as the shallow surface layer of coast-water extended over the Atlantic water. But it was found that neither these layers nor the living creatures drifting in them passed over

to the western mixed layers. This would only occur in the most northerly part of the Norwegian Sea where the speed and force of the Atlantic Ocean Current decrease. For the rest, we can only say that the coastal current keeps within the eastern area, but that the northern waters are constantly supplied with an abundance of nutritive matter and living organisms from the south, a state of things which explains why the region north of Lofoten, Finmark and the Barents Sea is one of the richest grounds for the maturing young of innumerable animal forms.

Arctic Winter Conditions.

In this region the temperatures are very near the "arctic" interval, though as a rule it may be said to correspond to a region in which the temperatures are several degrees higher.

In winter the temperatures are lowest at the two extreme ends — the Skager Rak and Finmark.

The Swedish researches in Skager Rak threw light on these conditions many years ago. Aurivillius (1898), for instance, demonstrated that a number of forms are present in winter in Skager Rak, which we have described above as being characteristic of the "arctic" layers outside East and West Greenland. Among these forms he mentions especially *Spadella hamata*, *Sagitta arctica*, *Calanus hyperboreus*, *Euchaeta norvegica*, *Thysanoessa inermis* and *Clione limacina.*

On the many cruises of the motor cutter "Morild" in the Møre area at all times of the year we never found *Clione limacina.* It is only when we get far to the north, as shown in Chapter II, that this form is found in the coastal water, whether it makes its way thither from the "Arctic Sea" or from the interior of the deep northern fjords. The farther we advance into the Barents Sea, the nearer we get to arctic conditions, as is clearly shown also by the lists of species published by Russian Scientists, Linko (1913), Derjugin (1915).

Schizopods in the Coastal Current.

In this connection it is particularly interesting to recall the information collected in regard to the distribution and biology of the Schizopods.

We have previously seen that the Atlantic species *Meganyctiphanes norvegica* chiefly occurs and spawns in the Mediterranean in winter, and on all the south-eastern banks of the Norwegian Sea, including the Møre bank, in summer. On the other hand the "little krill", *Thysanoessa inermis*, has the peculiarity that it occurs and spawns throughout the whole area of the coastal water in spring, when the cod spawns there, whereas it spawns in summer to the north of the cod's spawning grounds, especially off East Finmark. (See Chapter II, Figs. 42 and 43.)

In connection with the above observations we will briefly state our general views on the influence exercised by these conditions upon the appearance of the whalebone whales, referring the reader to Ingebrigtsen's treatise in this volume for a more detailed treatment of the subject.

The Blue-whale.

The blue-whale (*Balaenoptera musculus*) only appears in the Finmark Sea at the time of year when the small arctic species *Thysanoessa inermis* is spawning. It was precisely in the Varanger fjord, where, as we have seen, the "krill" spawns in such abundance, that FOYN began catching blue-whales. In summer this whale is also present off Bear Island, though never in the ice-cold layer of water which often surrounds the island, and only in waters well outside it, where the temperature is about 3° C. This exactly agrees with the facts described in regard to Davis Strait. As we know from the researches there in 1924, compared with SCORESBY's description of the old Greenland whale fishery, that the blue-whale and the Greenland whale frequented practically the same grounds, we can understand how, several hundred years ago and before the Greenland whale was exterminated there, whaling could be carried on off the coasts of Spitzbergen and in its fjords.

The blue-whale appears in spring in Denmark Strait and in summer to the north of Iceland, chiefly "in the boundary-layers between the ice and the warm water". Here we find, in the western mixed layers, parallels to the physical conditions which develop in summer in the northernmost parts of the mixed layers east of the Atlantic Ocean Current.

The Finner.

The finner or finback (*Balaenoptera physalus*) does not migrate so far as the blue-whale. The blue-whale may disappear from the Norwegian Sea and go far down in the Atlantic, as soon as the swarming time or pelagic period of the "krill" is over, but the finback (and the humpback) has learnt to shift its feeding ground in the Norwegian Sea in such a way that it can eat herring and caplin when there is no more "krill" left in the water in autumn and winter.

This, however, is tantamount to exploiting the supplies of "krill" in winter as well, inasmuch as both the herring and the caplin live mainly on "krill". The two species of fish can catch the "krill" even when it is located at the bottom; by eating these fish, therefore, the finback and humpback are able to feed practically the whole year round in the Norwegian Sea.

The migrations of these species of whales are certainly not altogether determined by their search for food. They also undertake migrations to distant waters to give birth to their young (see INGEBRIGTSEN's paper in this volume). But while feeding their migrations must be regarded as changes of locality necessitated by the changes which take place in the water itself. Thus, when the ice approaches the coast of Northern Norway, and the caplin swims in shoals towards the Murman Coast and the coastal banks of Finmark, the whales follow these fish on the move. When, on the other hand, the ice in summer opens up a great bay in the sea towards the east and north, these whales move far out from the coast across the valleys and slopes of the great Barents Sea.

Similarly the finners in the south-eastern part of the Norwegian Sea move from bank to bank according as they are able to catch "small krill" (*Thysanoessa*), herring, or "large krill" (*Meganyctiphanes*), as has been described in the preceding

chapter. Undoubtedly it is very fortunate for these finbacks, both in the south and in the north, especially in autumn and winter, that they can cross the Atlantic Ocean Current and reach the stores of "krill" in the bottle-nose grounds. "Whales and birds" have often been observed there at that time.

B. Fish along the Slope of the Continental Shelf.

1. The Herring.

An examination of the contents of the stomachs of fish living along the slope reveals in a great many cases, in addition to bottom fauna, both herring and squid — especially *Gonatus fabricii*. During the experiments on the Iceland-Faroe ridge a great many squid were observed, not only in the stomachs of the fish but also on the lines. On the north-eastern slope of the Faroe bank, at depths of 230—237 fathoms, herrings were found in the stomachs of most fishes: cod, halibut, catfish and *Macrurus fabricii*. In the month of June herrings have been found in great numbers in the stomachs of ling caught on "Tampen", in about 150 fathoms, by Norwegian and Swedish fishermen. In October 1902 the "Michael Sars" was steaming off the slope of the shelf of the Møre bank. At night a most brilliant display of phosphorescence was observable for a distance of many miles. Now and then a brilliant light flared up, as though an electric lamp was being switched on and off. Several *Gonatus fabricii* were caught on fishing hooks. The quick movements of these squid stimulate the luminosity of the surface plankton. (See Hjort 1905, page 188). We have just discussed the way in which herring and squid spread out from the slopes over the great deeps of the Norwegian Sea, and mentioned that much reliable material from these migrations has been received from Bottle-nose whalers and fishing experiments.

It must be confessed that the treatment of this unique material has been very inadequate, though it is some excuse that these experiments were made in days before the new technique of the study of herrings had been developed. There are, however, indications that the different stocks of herring have their own definite areas of distribution when they leave the banks which constitute their spawning grounds.

a) In his work on fluctuations (1914) Hjort tried to use the data regarding the relative numbers of the annual classes in samples of herring as a means of tracking the Norwegian herring out to the edge of the banks in the North Sea and there observing how these fish, when not too largely mixed with the Shetland breed, preserve the same numerical composition. The results of these investigations tend to show that the Norwegian stock of herrings keeps to the eastern slopes, from "Tampen" northward. (See Fig. 55). This is confirmed by the fact that herrings taken in drift-net experiments at a latitude of about 70° N. were from 28 to 32 cm. in length, the smallest specimens being immature and the largest spent.

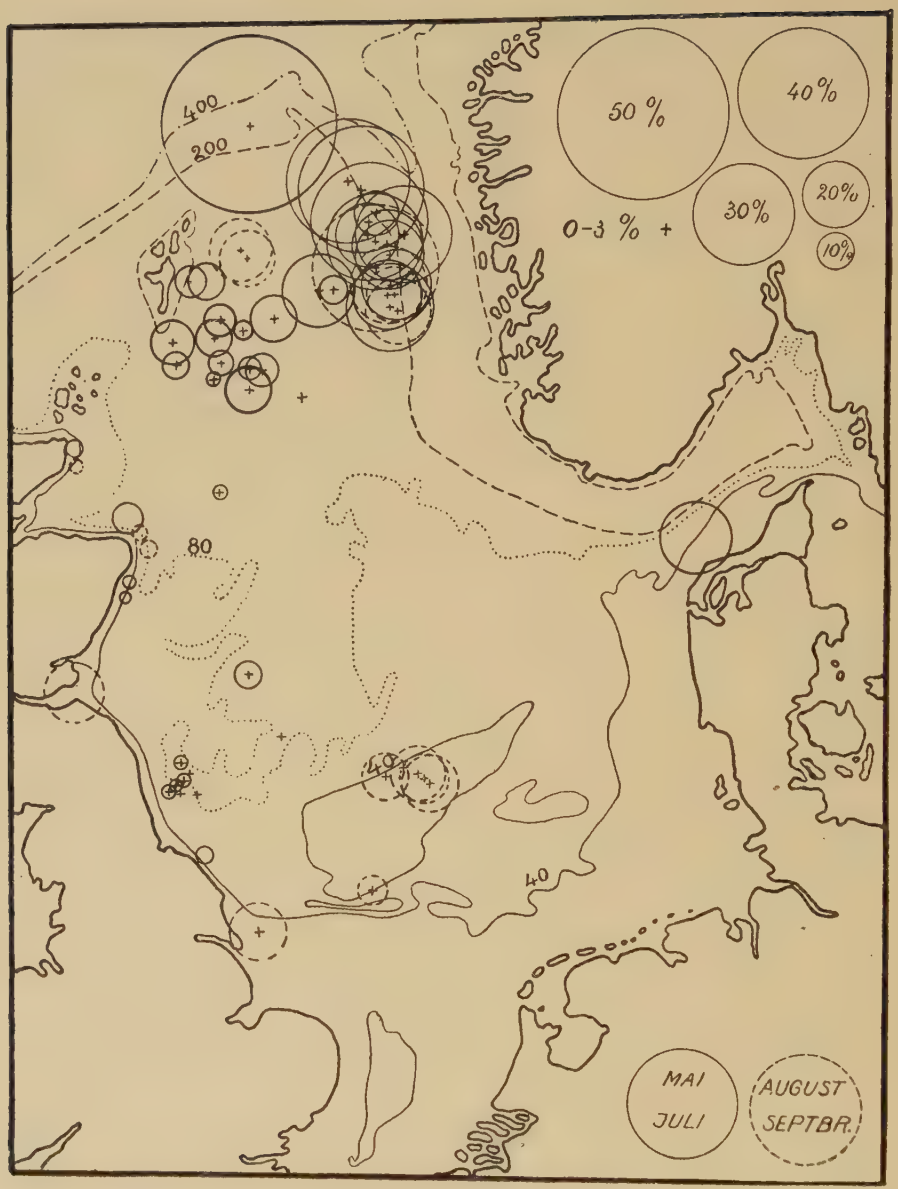


Fig. 55. Percentage of herrings of 1904 year-class in certain samples from the North Sea (1911).

b) The southern bottle-nose grounds (Fig. 49) seem to be frequented by the herrings from the northern North Sea (Shetland area), as herrings with a large roe and milt have been taken there in summer. Similarly some few herrings taken in drift-nets just on the western side of the Atlantic current had highly developed

roes in summer. Norwegian fishermen sailing for Iceland often see great shoals of herrings on their way. According to one of the reports some specimens were shot on the surface of the sea at 63°50′ N. and 4°30′ W.; their roes were far advanced (13th of June), and they were of very fine quality.

c) The autumn-spawning herring, which spawn in the south-eastern corner of the North Sea, move in winter into Skager Rak. During this migration they follow the slope of the North Sea bank, no doubt for the purpose of feeding on the *Meganyctiphanes* living there. Dr. O. Nybelin of the Swedish Hydrographical Commission has very kindly furnished us with information concerning his study of the Schizopods in Skager Rak.

He states that *Meganyctiphanes norvegica* has often been found in the stomachs of herrings, and he feels confident that there is a connection between the immigration of the herring shoals and the appearance in the waters of the Skager Rak of *Meganyctiphanes*. The life history of his species in Skager Rak does not seem, however, to have been elucidated yet by the investigations which have been made up to the present.

The observations to which we have referred here must be termed rather incomplete. Nevertheless they seem to us to show that the study of the life history of the herring should not be confined to the coastal banks where the herrings appear for a short period of their life for spawning only. It should be recognized that the feeding grounds of the immense spawning shoals are not limited to these banks, and that the great feeding areas are connected with the areas of distribution of that most important group of crustaceans, the Schizopods. The slopes of the Continental Shelf and the areas where the Atlantic water is mixed with melting water from the polar-ice or with fresh water from the rivers of Europe may be the real feeding grounds for the herrings.

By investigating the herrings in these extensive areas much information could be gained with regard to the areas of distribution of the different stocks of herring; and such information might afford much needed help in the studies which are at present mainly based upon the morphological characters of individual specimens.

2. Fish Caught on Lines.

In the line-fishing carried on from the "Michael Sars" in Davis Strait in 1924, and mentioned in Mr. Baldersheim's report on the fishing there in the following years, the fishes caught included: Species.

Norway Haddock
Cod
Halibut
Greenland Halibut
Witch

Long rough Dab
The common and the spotted Catfish
Tusk
Greenland Shark
Several species of Rays.

If we compare this list with the records of fish caught on the banks and slopes of the Norwegian Sea, we notice at once that Davis Strait is without three most important species of fish which play a very prominent part in the Norwegian Sea, viz.:

Haddock
Ling
Blue Ling.

It is highly significant that the carefully prepared lists of the fish off Greenland, issued from time to time by Adolf Jensen, agree on this important point.

Another equally fundamental difference between the two seas is the fact that herrings are absent from the Greenland waters, while quantities of Sandeels (*Ammodytes lancea* Cuvier) are found there instead. In addition to Ammodytes the Caplin (*Mallotus villosus*) is of extreme importance as food for the fish caught on lines. On the slopes in the southern part of the Norwegian Sea herring is the only fish found in the stomachs of the fish caught on lines, whereas the Caplin plays the chief part in the sea outside Finmark.

All in all the catches in Davis Strait greatly resemble the line-catches off Finmark. In the Finmark Sea (*vide* Fig. 21 area XI) cod, halibut and the two species of catfish similarly form the bulk of the catch on the slopes of the banks. Greenland halibut and long rough dab are also common there, although quantitatively they do not form such a large part of the catch.

A difference between the two areas is that the Finmark Sea contains great quantities of haddock, chiefly in places where the bottom is muddy. The absence of haddock and ling in Davis Strait is extremely interesting. Can it be connected with the fact that both these species spawn (in the North Sea and on the Møre Bank) in Atlantic water with a salinity of at least 35 $^{0}/_{00}$, which is not to be found in Davis Strait?

The blue ling is only of importance in the more southern slopes of the banks in the Norwegian Sea, especially in the region between Iceland and Møre and including the Møre district. This may be seen, too, from the fishery statistics, e.g. in the table on p. 46. That this species, which is everywhere found in the same places and at the same depths as the halibut, is absent from Davis Strait, where the halibut is found in such profusion, seems altogether inexplicable.

The blue ling spawns, as has already been mentioned, in very deep water on the south slope of the great barrier between the Atlantic and the Norwegian Sea. The presence of the young larvae has been observed on the surface above

these deeps, but the full-grown fish have not been seen in the actual process of spawning. Yet, as we have mentioned previously, the young larvae of the blue ling are found in company with precisely those forms, — such as the larvae of the Norway haddock and the arctic forms — which one would naturally expect to spawn also in the deep parts of Davis Strait.

The phenomenon is all the more remarkable inasmuch as the Danish researches in recent years have succeeded in showing that the early larval stages

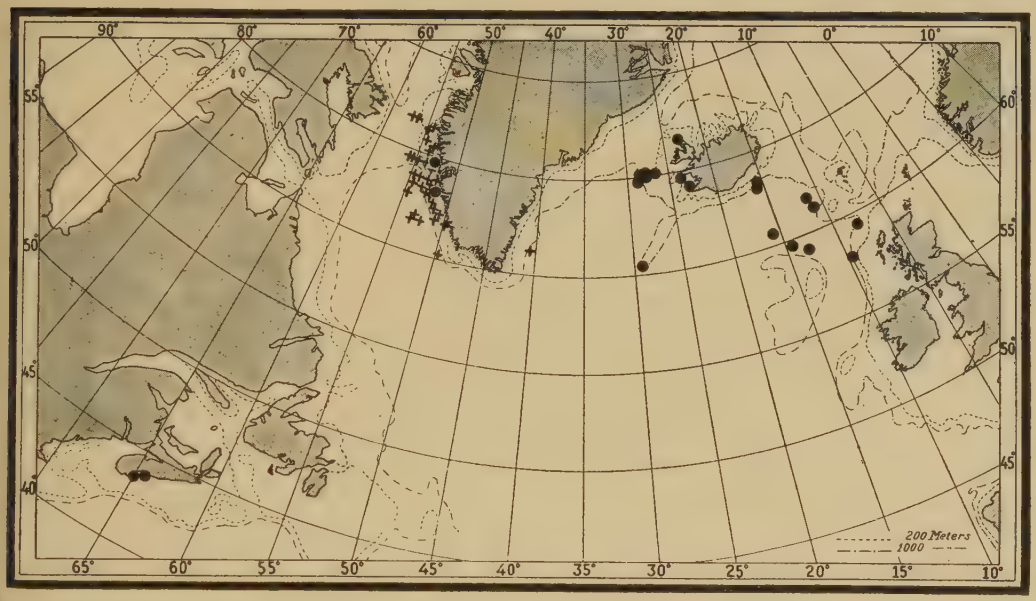


Fig. 56. All hitherto known finds of pelagic larvae of Halibut (*Hippoglossus vulgaris*, Flem.) + Greenland Halibut (*Reinhardtius hippoglossoides*, Walbaum) post-larval stages. "Dana" 1925. From Johannes Schmidt.

of the halibut also appear in the neighbourhood of the supposed spawning grounds of the blue ling.

Johannes Schmidt published in 1926 an extremely interesting chart (Fig. 56) which includes all the places where larvae of the halibut and the Greenland halibut have actually been found, and at the same time put forward the striking hypothesis that these species only spawn in deep water — say at a depth of 1000 m. or so — outside and to the south of the Norwegian Sea, and never in that sea.

This surprising hypothesis can hardly be said to be proven yet. Nevertheless it seems perfectly justifiable to use it as a working hypothesis; for apparently the fact is indisputable that no larvae of halibut or Greenland halibut have been found in the Norwegian Sea. Before these larvae could be systematically identified we did not appreciate this point and various mistakes were made. On the other

hand it must be confessed that we have done too little fishing with suitable gear for catching halibut larvae in the Norwegian Sea; so the hypothesis in question may have to be modified. At any rate this much is certain, that the area outside the Norwegian Sea, on the slope facing the Atlantic and stretching all the way from Davis Strait to the slope of Scotland, is the largest North Atlantic spawning ground for many species of fish, including the halibut; and in consequence great numbers, if not the majority, of the halibut which grow up in the Norwegian Sea originally come from there.

Of course, this hypothesis logically involves many other postulates. Thus we must assume that the large, sexually mature halibut migrates for very long distances every year. If the hypothesis is correct the halibut must migrate for spawning purposes from the north of Norway to a region south of the Faroe-Shetland ridge and back again; just as the cod migrates every year from the Finmark Sea to Lofoten or the Møre bank and back. It is certainly high time that the fishery researches in the Norwegian Sea should try to obtain a more intimate knowledge of these problems.

Quantities. If we compare the catches in Davis Strait and the Norwegian Sea from a quantitative point of view we cannot fail to be struck by the surprising and epoch-making fact that, in the years 1927 and 1928, the "Helder" Expedition alone was able to catch more halibut than all the Norwegian bank-fishing vessels together could take in the waters between Iceland and Finmark. The only possible conclusion would seem to be that the stock of halibut in Davis Strait during the two years in question was enormously large, far greater than in any other area where bank-fishing has hitherto been carried on in the Norwegian Sea. That the stock of cod was also extremely large in those years seems beyond question. First we have a consensus of evidence from all who tried fishing on the banks, then the big catches, and finally the halibut fishers' fear lest they should get into the swarms of cod "which monopolized all the hooks on the lines."

Further, we must apparently conclude from all this that the stock of fish in Davis Strait has been greatly underestimated, and we may and should anticipate that attempts will be made, by others than the Eskimos, to exploit this abundance. The "Helder" Expeditions have unquestionably proved the possibility of carrying on, during the last few years, a "pelagic" and remunerative fishery, without calling at or receiving assistance from the coast. And this has been done in a particularly efficient way, both as regards methods of fishing and preservation. It is evident that the excellent method of freezing the halibut is decidedly better and commands much higher prices for the fish than either salting or canning, which have been the only forms of preservation practised by the Eskimos.

On the other hand there is a certain amount of truth in the objection that we still lack satisfactory proof that the fish in Davis Strait will suffice for an annual expedition of such large dimensions. Obviously an undertaking of this size, which

has to sail 5000 nautical miles, must have big gross budget, and the income must be very large in order to cover the expenditure. Will the annual yield of the stock of fish be sufficient to cover expenses?

Clearly these problems can only be solved in the light of future experience. Meanwhile, however, it is interesting to review the problems which ought to be studied.

Previous experience of other seas and other fishes, e.g. the plaice in the Barents Sea, has shown us that the first fishermen to begin intensive fishing on "virgin ground" could secure these large catches because they were not catching the annual new additions to the stock, but what has been termed an accumulated stock, i.e. a stock whose mortality has not been affected by any fishery. Presumably the same state of things existed in Davis Strait in recent years. The small amount of halibut caught by the Eskimos in earlier years may be left out of account altogether.

Another well-known fact with regard to an "accumulated surplus" of this nature is that the first fishing often operates to the advantage of the stock, because the fish have been too thick on the ground and therefore have not grown sufficiently large. Accordingly there should, perhaps, be an improvement in the state of affairs for a time, unless the fishing is so intensive that too few fish remain to exploit the food in the sea and form the rational basis of a fishery.

Biological Observations of the Stock of Cod and Halibut.

These facts are mentioned here primarily with the object of directing attention to the various problems, so that they may be investigated and the stock of fish subjected to observation, with proper age analyses, during the years to come. On the cruise of the "Michael Sars", collections were made of cod and halibut otoliths, which, though too few to give a representative picture of the conditions, may deserve mention here on account of their rarity. Dr. Hjalmar Broch has done us the great service of examining this material for us, and on the basis of his report we will discuss the problems raised, so far as the material goes.

Cod.

The length measurements embrace 87 specimens taken on lines on Fyllas bank and the southern part of Lille Hellefiske bank, and the ages of 81 of these could be determined with certainty. As the fish were caught on lines (one or two, by way of exception, on hand-lines) we must base our comparisons on line-fishing elsewhere. Comparison with the catches in Norwegian waters reveals several points of considerable interest which may be of importance for future researches.

The lengths vary from 69 to 140 cm., the average being *93.6* cm. For the sake of comparison it may be mentioned that Sund (1927), reporting on the Norwegian cod fishery in 1924, gives 90.1 cm. as the average length off Møre and farther to the south, while the figure for Lofoten is only 87.5 cm. Considering that the average measurements for 1924 as given in Sund's reports were exceptionally large — in 1925 and 1926 they were 89.5 and 83.1 cm. respectively in the Møre district, while in the same years they were 84.4 and 83.2 cm. in Lofoten — we

seem justified in inferring that the cod of the Greenland banks were larger on an average than the cod of the Norwegian Sea.

The conditions as regards growth and the composition of the catches as regards age furnish some interesting data for elucidating the underlying causes. The numbers for the different year-classes are shown in percentages in the following table:

Table 15.

	Year-class											
	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909
Davis Strait 1924	..	..	1.2	3.7	8.6	6.2	3.7	22.2	31.0	14.8	7.4	1.2
Lofoten cod 1924 (Sund 1927)	..	2	2	18	8	33	10	7	14	3	1	1
Lofoten cod 1925 (Sund 1927)	1	18	12	28	8	22	4	2	3	..	..	..

In the material from the Davis Strait the later year-classes from 1914 onwards are, on the average, only represented by small numbers.1916, with 8.6 per cent., stands highest among them. The bulk — no less than 68 per cent. — is made up of the year-classes for 1911, 1912 and 1913, and among these one, that for 1912, includes no fewer then 31 per cent. of the specimens and is thus the year which predominates over all the rest, and still sets its mark on the stock of cod on the banks in Davis Strait even in 1924.

A comparison with the conditions in Lofoten in the years 1924 and 1925 shows that the year-class of 1912 was still the dominant one among the older classes of cod in 1924, and Sund's tables show that the 1912 class made up no less than 28 per cent. of the mature Lofoten cod in 1922. We can also follow the history of this class a little farther back. (See, *inter alia*, Hjort, 1926). In the Finmark fisheries — which catch immature young cod — we can trace the 1912 class even in 1916, and in 1918—1919 it is the cause of the large catches, while the cod fishery in Lofoten — catching mature spawning cod — is still based on older stock in those years. In 1920, on the other hand, there is a sudden change: the immensely prolific 1912 class dominates the whole fishery. The same may be said of 1921, but after that the "peak" seems to have gone; the intensive fishing has decimated the year-class, and the subsequent years, with a more normal average yield, still further decimate the old stock, while only negligible numbers of new recruits enter the ranks from the young year-classes. Even if, thanks to the increased weight of the specimens caught, the yield shows no decline parallel with the drop in numbers, there must ultimately be a reduction of the yield until other prolific year-classes arrive to form new "peaks".

Reverting to the conditions in Davis Strait, there are two points worth notice. First, it is again the 1912 class which furnishes the main body of the cod; in other words the 1912 class was exceptionally prolific on both sides of the Atlantic.

In this connection it is interesting to remember that an earlier year-class which played a most important part in the Norwegian herring and cod fisheries, namely the 1904 class, was also the predominating class among the Newfoundland herring caught in 1914—1915 (see HJORT 1915).

Second, it is clear that while the 1912 class predominated on the banks in Davis Strait as late as 1924, this class had ceased to play a markedly leading part in Lofoten by, approximately, the year 1922. This circumstance should probably be put down to the intensive fishing in the Norwegian Sea, as compared with the almost entire absence of any fishery on the banks in Davis Strait. The Greenland fisheries are carried on near the coast, and the particulars kindly furnished by Prof. ADOLF JENSEN show that this fishery should rather be compared with the Finmark fishery, because the fish caught are practically young classes only, up to the age of about six years. Unfortunately, therefore, these fish furnish no guide in our investigation of the stock of large cod belonging to the banks.

Perhaps we may assume that the stock in Davis Strait, as we know it from the fish caught there, presents a pretty accurate picture of the conditions in unfished waters. We find that the previously mentioned 1912 class played a very important part in Davis Strait even in the twelfth year, whereas its rôle was at an end in Lofoten two years earlier. This suggests that the fishing in 1924 in Davis Strait had not decimated the stock to the same extent as the fishery in Lofoten. But in addition it is interesting to study the size of the cod and compare this with the rate of growth as we know it in the Norwegian Sea.

The subjoined table gives particulars of the average lengths of the various year-classes in Davis Strait and the Norwegian Sea so far as the material and available information allow.

Table 16.

Age (completed years)	Average lengths in cm.		
	Davis Strait 1924	Røst (Lofoten) 1913 „Skrei" (mature cod)	North Norway 1913 line-fishing
6	76	..	56.3
7	78	63.9	62.2
8	79.5	67.1	66.2
9	84	73.6	73.9
10	102	80.6	80.1
11	106	84.5	..
12	110	107.0	..
13	116	..	..
14	115	..	..

(The figures in the two columns on the right are from HJORT: Fluctuations in the great fisheries of Northern Europe. 1914.)

It will be seen that the growth of the Davis Strait cod is markedly more rapid than that of the fish in the Norwegian Sea. When 6 or 7 years old the cod in Davis Strait are fully as large as 9 year old fish in the Norwegian Sea; and 9 year old cod in Davis Strait are as big as 11 year old Lofoten cod. This shows that the food supply in Davis Strait must have been very abundant although the stock of fish was so large at that time (in 1924).

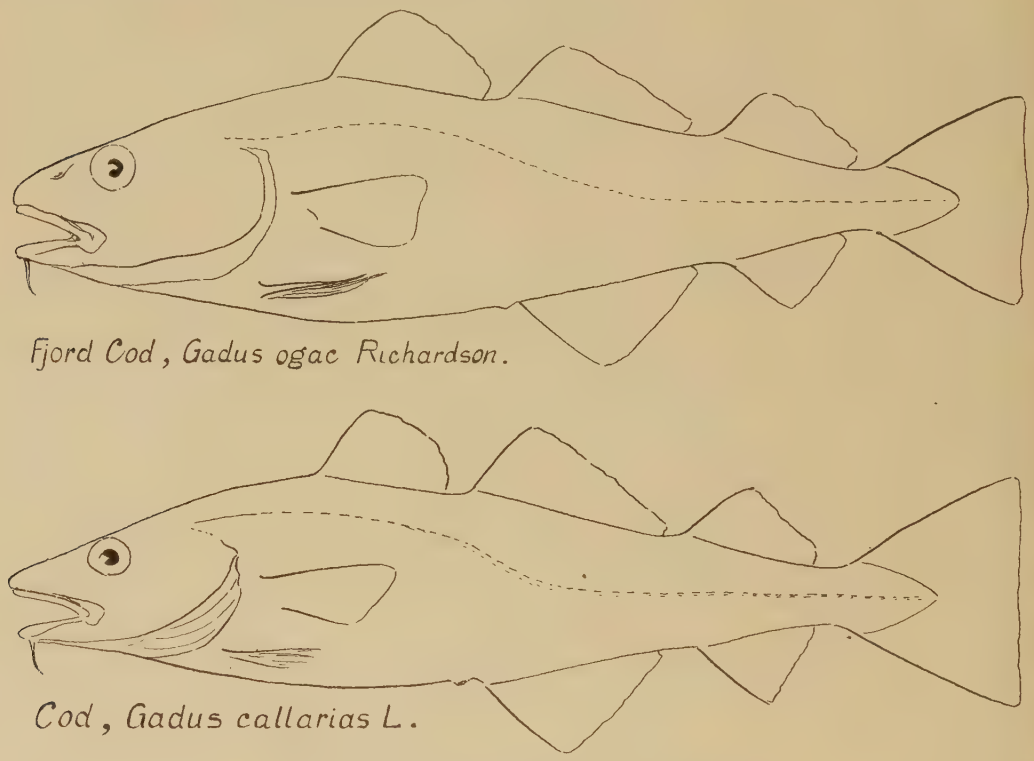


Fig. 57. Drawn by Thorolv Rasmussen.

The Danish fishing researches began in 1925, under the direction of Professor Adolf Jensen, the study of the biology of the cod in Davis Strait and the Greenland fjords. The report on these investigations (Jensen 1925) states that a survey has been made, for the first time, of the spawning conditions on the banks and in the mouths of the fjords. Professor Jensen has been good enough to inform us that the material for determining the ages of the fish is being dealt with now, in order to find out the fluctuations in the year-classes of the stock.

In the report mentioned he writes that he has been struck by the great difference between the stocks of cod in the two periods of his researches on the Greenland banks. In 1908—1909 he found no cod worth mentioning except in one

or two fjords; but in 1925 there was cod in a large number of fjords and along considerable stretches of the coast. In 1908 he fished without result for cod on Fylla's bank, at a season when there was cod on the same bank in 1925. Similarly he fished unsuccessfully for cod later in 1908 inside Fylla's bank, i.e. in Godthaab fjord, though considerable quantities of this fish were caught there in 1925.

In Professor JENSEN's opinion the conditions must have altered there in the intervening years; as regards the coast he would indicate 1917 as the year

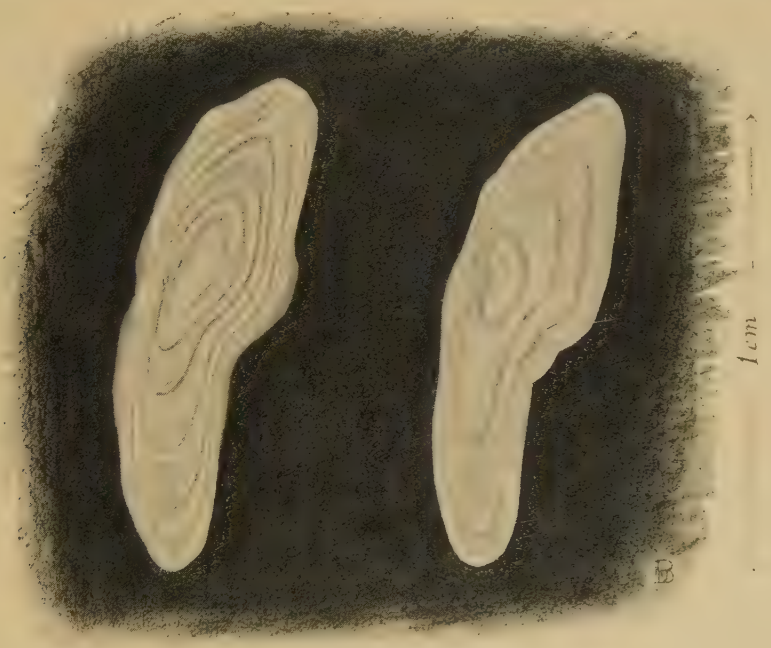


Fig. 58. *Gadus ogac*, otoliths in transverse section. To the left from a specimen seven years old (with seven "winter-rings"), to the right of a four years old individual; the total length of the ogac was in both cases 44.5 cm. Drawn by HJALMAR BROCH.

of the change. In that year the cod began to appear in large numbers in the Julianehaab and sometimes in the Fredrikshaab district; while the Godthaab and Sukkertop district, farther to the north, had good cod years later on in the 'twenties.

If it is correct to assume that young fish are caught in the fjords it is remarkably interesting that Professor JENSEN indicates 1917, when the 1912 class was five years old, as the particular year of the change. At that age the young fish caught off Finmark begin to be of importance for the line fishing. It is interesting. too, that the numbers of young fish first make their appearance in the south and gradually become more numerous farther to the north.

Judging, however, from Mr. BALDERSHEIM's report, we ought not to assume

too readily that unsuccessful fishing attempts on Fylla's bank at one particular time of the summer are evidence that there were no large stocks of cod in Davis Strait. That report, which embodies a far greater wealth of experience, shows that the shoals of cod and halibut move about according to the food and temperature conditions, and that vast quantities of fish may be present in the sea, even though one particular bank may be deserted at a given time.

We must confess, therefore, that our knowledge of these matters is at present rudimentary.

The Fjord Cod

Otoliths and Scales were taken from five specimens of this species. The scales were not very clear but the otoliths are clear and often quite schematic in their proportions, as the accompanying drawings (Fig. 58) of otoliths show. From so small a number it is only possible to infer that the growth seems normally to be near its completion when the *ogac* is about half a metre long. The proportions noted are compared below:—

Table 17.

Length in cm.....	44.5	44.5	44.5	46	47
Age (completed years)	4	5	7	4	7

Halibut.

Whereas the scales are difficult to use in the case of the halibut on account of the new scales which are constantly formed, the otoliths, however, are very clear. Otoliths of 10 halibut were taken; only in one case, that of a specimen 214 cm. in length, was it quite impossible to interpret the picture given. The next largest specimen, measuring 130 cm. was aged either 15 or 16; owing to the uncertainty it has been omitted from the table. If we compare the few data from Davis Strait with JESPERSEN'S results for the corresponding year-groups in Iceland waters we arrive at the following figures (following JESPERSEN (1917) heavy types are used for the estimated average size between the measured minimum and maximum sizes; all lengths are given in centimetres):—

Table 18.

Age	Davis Strait	Faxe Bay	North-west Iceland	East Iceland
6.....	72	53— **65.3**— 87	48—**61.1**— 76	29—**46.3**—73
7.....	84	55— **70.1**—104	52—**65.9**— 84	36—**61.6**—79
8.....	75—80—83	58— **73.7**—103	64—**73.3**— 85	49—**66.3**—86
10.....	85	75— **95.3**—141	72—**87.3**—106	66—**84.0**—94
13.....	92	111—**123.3**—140	117	..
14.....	108	116—**135.5**—155	..	..

According to these figures the type of growth would seem to agree with the quick-growing halibut in the waters of West and North-west Iceland. So far as one can judge at all from such scanty material, it seems as though the conditions for the growth of a large stock of halibut in 1924 were very good.

C. The Slope of the Continental Shelf considered as a Biological Facies.

Quantitative Distribution of Fish according to Depth.

The French deep-sea expeditions in the "Talisman" and the "Travailleur" and the Norwegian "Michael Sars" expedition of 1910, carried out a series of systematically planned trawl-net hauls with a view to obtaining quantitative data regarding the distribution of fish at different depths along the slope from the coastal banks to the wide deep plain of the Ocean.

In "The Depths of the Ocean", page 422, the results of the French trawling are summarized, and these results are compared in the subjoined table.

Table 19.

4	hauls	between	0	and	100	metres	gave	224	fishes,	or	56	pr. haul
9	—	—	100	—	200	—	—	323	—	-	36	—
6	—	—	200	—	500	—	—	1275	—	-	212	—
28	—	—	500	—	1000	—	—	1044	—	-	37	—
29	—	—	1000	—	2000	—	—	905	—	-	31	—
20	—	—	2000	—	2900	—	—	115	—	-	6	—
4	—	—	2995	—	4000	—	—	61	—	-	15	—
6	—	—	4000	—	5000	—	—	10	—	-	2	—

Even down to 500 fathoms the "Michael Sars" obtained as many fish as on the bank, viz. about 300 fish in one haul. At the same time the trawl was also crammed with other marine animals.

In his "Challenger" Summary Sir John Murray has attempted an explanation of the quantitative distribution of animal life at different depths. He started from the observation that a great many deep-sea animals had developed special apparatus for catching the minute shells and particles of food that sink from the surface waters and that the intestines of the holothurians and other echinoderms — the most abundant of deep-sea creatures — were always crammed with the top layers of the deposit on which they were captured.

The mud-line theory.

Murray termed the limit of wave action the mud-line, and the average depth in the open ocean at which the mud deposit commences was placed by him at about 100 fathoms. This region is, according to Murray, the "great feeding ground" of the Ocean, and it is especially around the continental shelf that organic particles from the continents slowly come to rest on the bottom and supply food for the wealth of crustaceans which are found in such situations (*Calanus*, *Euchaeta*,

Pandalus, *Hippolyte*, *Phasiphae*, *Crangon*, *Pagurus*, *Amphipods*, *Isopods* and above all *Schizopods*).

The mud-line theory has exercised a great influence on the marine biology of the last thirty years. During his work in the Limfjord C. G. Joh. Petersen arrived at the conclusion that the plankton played a very unimportant part in the food of the bottom fauna. He discovered that the uppermost layer of mud on the fjord bottom, 2 or 3 mm. in thickness, consisted of detritus containing minute remains of organisms mainly from decayed plants from the littoral region, and that only this upper layer of the mud has any nutritive value. The deeper blue-black layer does not occur in the gut of the bottom animals.

Globigerina ooze.

On the "Michael Sars" expedition in 1910 the discovery was made that the bottom deposits on the Atlantic slope off the west coast of the British Isles were not of terrigenous but of planktonic origin and that most of the fauna of the continental slope lives on *Globigerina ooze*. The experience of the fishermen does not confirm the mud-line theory that the depth of bottom deposits serves as a measure or even an indication of the abundance of life along the sea bottom. In any case are the conditions of life different in the deeper parts of the Sea far from land. In "The Depths of the Ocean" Hjort expressed this view as follows: "Where the water is in motion at the bottom, a fine cloud of organic matter is swept along and in such localities the mud-eaters thrive in great quantities. The fishermen have for a long time profited by this fact, for they do not seek those places (as in pits and channels on the bottom) where mud is laid down, but choose rather the spots where the bottom is covered with coarser particles, and where the finest mud cannot settle. In these places the fish find most food, and the fishermen most fish. The presence of corals like the *Lophohelia* over great parts of the slope of the Norwegian Sea is a most interesting indication of the motion of the organic matter along the sea-bottom."

Many years ago G. O. Sars (1872) investigated the sea banks outside the west coast of Norway. This investigation was carried on in four different localities: (1) from the deep sea outside Storeggen, (2) and (3) from two separate places on Storeggen, and (4) at "Mebotten" on the bank.

Writing about this Sars says: "The animal life on and outside of Storeggen must, judging by my very cursory investigations, be quite remarkable in its profusion....", and further, in regard to the bank itself, "the animal life there did not present the same luxuriant variety as Storeggen itself, but as I was fortunate enough to be able to use the dredge at all these three places the number of animal forms collected there is far greater." This means that Sars found that Storeggen had a very abundant bottom fauna, which was richer than what he came across on the bank farther in. A perusal of Sars' list of marine animals taken on Storeggen is enough to convince us that the animal life there chiefly consists of creatures which prefer water with strong currents, including some which are characteristic

denizens of *Lophohelia* banks. We may name at random forms like *Arcturus*, *Terebratula septata*, *Echinus norvegicus*, *Astrophyton caput medusæ*, *Muricea placomus*, *Allopora norvegica*. On one occasion we ourselves, when trawling with a net which went to the bottom and was damaged by stones and gravel, found *Meganyctiphanes norvegica*, which in the circumstances was probably caught right down near the bottom.

Floating Organisms and organic Matter just above the Sea-bottom.

An interesting problem for future research would, no doubt, be the quantitative aspect of the floating organic matter and the smaller organisms on the sea-bottom or in the nearest layer of water just above it. Investigations of this kind were made many years ago at Drøbak in the Oslo fjord by Hjort, who towed a silknet supported by a sleigh that was dragged along the bottom. In this way it was ascertained that a great wealth of fauna, consisting of *Calanus finmarchicus* and *hyperboreus*, *Euchaeta* and Schizopods, was present at times (in winter) when such creatures could not be caught in the upper layers of the water. Similar investigations have lately been made by Roderick Macdonald (1927) in the Clyde Sea area.

He has found that *Meganyctiphanes norvegica* in the West Scottish firths is a "suspension feeder"; and in the Clyde Sea area it is met with, as a rule, 10—20 fathoms above a muddy bottom. Macdonald has also made several series of tow-net hauls in order to find out whether there are any vertical migrations. It was discovered that *Meganyctiphanes norvegica* — as well as *Thysanoessa raschi*, *Calanus finmarchicus* and *Euchaeta norvegica* — is in the habit of making vertical migrations; but these species may be found at any time of day or night quite close to the bottom, and in the middle of the day they are most abundant just over or at the bottom.

Investigations of this nature have never been made along the bottom of the slopes, so our knowledge of its conditions of life is admittedly based upon conclusions drawn from observations elsewhere, rather than upon what has been observed there.

Meanwhile, until a more systematic treatment of these questions becomes feasible, it is not without interest to summarize the chief facts, which are bound to play an important part in future discussions of these questions.

Current Measurements over Storeggen.

In his treatise in the present volume Martens gives a summary of early and recent measurements of the currents over the Møre bank (Storeggen). He found that the speed of the current over Storeggen in summer, from the surface to the deepest water, is 5 nautical miles in 24 hours. In spring the speed is doubtless greater, and farther to the south, off the stretch of the coast south of Stat, where the coastal water forms a narrower current, it also doubtless attains a greater speed. The particles of water which cross the Storeggen section at a given moment may be assumed to have crossed Stat some three weeks earlier, and the Lindesnes (in Skager Rak) about 10 weeks before.

In all our deliberations on the phenomena of the slopes we must remember that we are dealing with moving layers of water, and that we must avoid picturing the conditions as static. This applies to all the problems of the life produced in these waters, and the food of the fauna at the bottom.

The Production of Plankton in the Sea above the Slopes.

On two very important parts of the slope of the Norwegian coastal banks it has been found that there is a remarkable output of vegetable plankton in spring just above the "edge"; and this output seems to have no connection with the output of plankton which takes place simultaneously close to the coast. For in both places there were two separate areas of prolific plant life. Thus, Mrs. Birgithe Ruud Føyn (1926) discovered an abundant output on the Vesteraalen "edge" itself (see Chart 21, area IX), which had no connection with the output in the Lofoten section; and Gran (see his paper on Møre in the present volume, page 54) found that there was an abundant growth above Storeggen, having no connection with the simultaneous output near the coast.

The hydrographical sections agree in an interesting manner with this, as they show that there was a layer of fresher water on the "edge", of the same salinity as the coastal current, though the water in between had a higher salinity.

It is also interesting to note in this connection that Ruud is able to show (in his paper in this volume), that there was an independent spawning and development of *Calanus finmarchicus* on the "edge", geographically separated from the spawning of the same species which took place near the coast and in the Romsdal fjord.

Biochemical Problems.

On the interesting problem as to what causes this development in each case, nothing can as yet be said with any degree of certainty. This problem is closely connected with biochemical questions which are very live issues at present — namely those involved in the attempt to discover whether spring is the time when the sea contains an ample supply of the minimum requirements for the development of plant life. Our own organization will shortly be in a position to study the problem in the following way.

Sections will be investigated, before, during and after the season of this development, from the coast and out across the banks to Storeggen, in order to determine the temperatures, salinity, and quantities of oxygen, p_H, ammonia, nitrates and phosphates at all depths from the surface to the bottom. This, it is hoped, will furnish us with fuller data for deciding which of the two hypotheses advanced in explanation of the phenomena carries most weight.

On the one hand it has long been known that a very homogeneous layer of water is formed in autumn in the sea off the coast of Norway, extending from the surface to a depth of several hundred metres. This would serve as a medium for transporting food-stuffs between the surface and the deeper layers. Compare Fig. 59, which illustrates the variations of temperature at the same station off the coast of Norway.

Sund (1929) has furnished interesting information to the effect that he has discovered high nitrate and phosphate values in the surface water in winter, just at the time when the layer of water is homogeneous and before the fresh water coming from the land in spring gives a fresher quality to the surface of the sea.

On the other hand Gran (in the present volume) points out that precisely this fresh water emanating from rivers and melting snowfields probably supplies the nutriment needed to promote the development of the plant life in question.

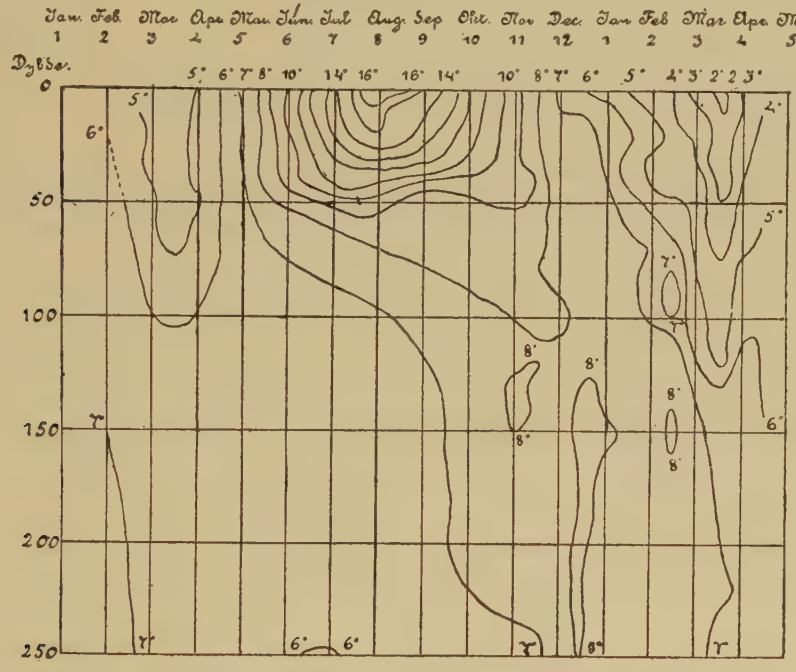


Fig. 59. Variation of Temperature according to Depth during different Seasons off the Norwegian West Coast, from Hjort.

But, as we have said, we consider it too early to take up any definite standpoint in regard to value of these working hypotheses. Nor do we feel sure that the production of plant life, which occurs in a given spot on the surface of the sea above the "edges" is really of so much importance of the adjacent localities.

Supplies from other Localities.

Here we must always bear in mind that the water is in constant motion, chiefly in an unvarying direction. In his paper on the Møre region in this volume Gran points out that the plant forms which develop in spring are neritic in character. "According to our knowledge of the direction of the current in these areas, they must either come along the Norwegian coasts from the northern part of the North Sea or in the Gulf Stream from the waters about Shetland."

Gran endeavours to prove, from the distribution of the various species,

that considerable supplies of plankton come to Storeggen both from the Faroe-Shetland channel and from both sides of the North Sea.

The quantitative investigation by Ruud of the stock of *Calanus finmarchicus* also indicates that large and important supplies of plankton come from the parts of the slopes which are washed by the current on its way to Storeggen.

A highly important, perhaps the main, source of the fauna of the slopes is without doubt, therefore, the production which proceeds along all the slopes where the current passes. This makes it easier to understand that similarity in the composition of the species of fauna which we found to be so characteristic of all the southern or south-eastern slopes in the Norwegian Sea and the North Sea, and which we demonstrated more especially when dealing with the Schizopods.

Here, however, it is important to remember the fact, already noticed in the section on Plankton Communities, that the Atlantic forms which enter the Norwegian Sea are largely mixed with species which cannot live in the Norwegian Sea, and in consequence perish and are cast up on the coast-banks or even on the shores of Norway. These supplies which are brought by the current also appear to play a very important part in the economy of the banks along the coast.

Importance of the Schizopods in the Economy of the Slopes.

Among the organisms which occupy a central place in the "economic system" of the fauna, if we may use such a term, the Schizopods are certainly the most important. In the present treatise we have started from the assumption that these creatures are best described as denizens of the bottom, in as much as they get most of their food at the bottom of the sea. Along the bottom they obtain the organic foodstuffs which are brought, in the form of small dead or living organisms, by the current. Here the "krill" itself supports many creatures, and especially those fish (particularly the herring) which at certain times of year visit the slopes in order to catch "krill". The herring is, in its turn, an important means of subsistence for all the species of fish that the fishermen catch on long lines, these being the old and mature fish which make for the slopes as soon as they have finished spawning and then seek the richest feeding ground.

We have also tried to give our reasons for believing that it is only during the "swarming" seasons that the great masses of "krill" rise from the sea-bottom to the surface in order to spawn there. This allows the early stages of the "krill" to enjoy the plants and zooplankton produced on the surface. It is chiefly or only in this swarming season that the "krill" is available for the whales, forming the sole food of the blue, finback and humpback whales. This is why these species of whales visit the spawning grounds of the "krill" at the time in question and remain there only during that season.

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WHALES CAUGHT IN THE NORTH ATLANTIC AND OTHER SEAS

BY

ANDR. INGEBRIGTSEN

Introduction.

This paper has been written on the suggestion of Professor JOHAN HJORT, with whom I have been discussing the subject for several years.

In the preparation of the chapter relative to the survey of the occurrence of whales in the Arctic Ocean off Finmark and Bear Island use has been made of the log-books kept by M. A. INGEBRIGTSEN, whaler, on his whaling boat "Skytten" from 1896 to 1908. These logs have previously been used by Dr. JOHAN HJORT in his book "Fiskeri og Hvalfangst i det Nordlige Norge" (1902).

I have also had the opportunity to make use of the statistical informations collected by the Norwegian Whalers' Association.

Besides, the present paper chiefly contains my own experiences during thirty years of practical whaling in various waters, on the basis of which I beg to express my opinion on the problems of the modern whaling.

The Humpback.

Winter Migration.

This species of whales was found off the coast of Finmark at the beginning of February and disappeared at the end of March, in some years later.

According to the "Skytten"'s log-book the following humpbacks were captured in 7 years:—

1896,	first shot	28/II,	last shot	10/IV,	total	winter	capture	15
1898,	—	12/II,	—	12/III,	—	—	—	14
1899,	—	17/II,	—	17/III,	—	—	—	11
1900,	—	9/II,	—	12/III,	—	—	—	17
1901,	—	2/II,	—	6/IV,	—	—	—	21
1902,	—	25/I,	—	20/III,	—	—	—	25
1903,	—	26/II,	—	16/III,	—	—	—	3
							Total	106

As a rule the humpback appears off land between Fruholmen Lighthouse to the west and the North Cape to the east. Whaling boats which had their stations

in that district had therefore a larger capture of humpbacks during the winter than boats which were stationed in the eastern part of Finmark.

From the moment the humpback approached the coast it continued westward up this as far as Sørøen, where contact with it was lost because it went off to the west and left the coast.

During its westward migration the humpback often approached close to land. At Fruholmen it frequently passed inshore of the lighthouse, between the numerous surrounding islets and skerries.

At Knivskjærodden, just to the west of the North Cape, it also went quite close to the shore. It frequently happened that the whaling-boats lay waiting for the humpback to come outside the four mile limit in which capture was not allowed.

One winter the whaling station at Troldfjord was visited by 4 humpbacks which stayed in the harbour a whole day. They went quite close to the quay and buoys.

The reason why the humpbacks went so close to land was probably that they found the current running less strongly against them there than farther out to sea.

At the beginning of the winter migration, before the caplin had approached land, the humpbacks captured had quite empty stomachs.

Later on in March and April they would sometimes stop in the caplin shoals, take a mouthful of food and then proceed westward. Food seemed to have no great interest for them.

In some years, however, the humpbacks would stop and collect at the mouth of the Varanger Fjord in order to eat caplin.

In such years the migration to the west presumably approached the coast in the eastern part of Finmark; and this, again, must have been due to the fact that the stock of humpbacks kept farther east in the Arctic than usual.

Whales captured in winter off Finmark were all very fat and in good condition so that the conditions of nourishment in the north eastern Arctic must have been very good during the autumn and the beginning of winter.

Unfortunately during that whaling period off Finmark no proper records were kept of whales which were landed at the stations, but it is known with certainty that the majority of adult females were pregnant with large foetuses.

Professor Collett, who visited the whaling stations in Finmark, tells us in his book "Norges Pattedyr" (1912) that the foetuses in the humpbacks which were caught off Finmark in the winter were from 12 to 14 feet long.

One female humpback shot on March 10th, 1898, had a foetus 14 feet long, and another female shot on the same day had a foetus 12 feet long.

But simultaneously with these large foetuses there were also found smaller ones, from $1^1/_2'$ to 6′.

This irregularity in the size of the foetuses at one and the same time shows

that the time of mating amongst the humpbacks may vary considerably. This also applies to other species of whales.

We may conclude from the few available records of measurements of pregnant whales off Finmark that the female humpback must attain a normal length of 45′ before it is sexually adult.

In the case of the humpback, as of the other whale-bone whales, the blue-whale, the fin-back and the sei-whale, the females attain the greatest size, and during the period of gestation are fatter than the males of the same species.

The reverse is true of denticete whales, where the males are the largest (e.g. the sperm whale and bottle-nose whale).

As mentioned above, the humpback disappeared from Finmark in a westerly direction in the sea off Sørøen.

Since 1918, when whaling began off the coast of Møre, and until this year (1928), I have only heard of one case of a humpback being seen in those regions in winter. This was in March 1922 off Smøla, about 30 nautical miles from the coast. It may therefore be said with certainty that the humpback no longer occurs in numbers off the west coast of Norway in winter, in February, March and April, or at any other season of the year.

Professor Collett (1912) says that the humpback has appeared during the great herring fisheries off the west coast during the autumn and winter and that it has penetrated right into Skager Rak, in the direction of Sweden. In 1890—1891 there were shoals of humpbacks in December outside the Kristiania (Oslo) Fjord, ten being shot there during those two years. Again in the year 1895 several were shot off Haugesund in the month of March.

It is certain that the humpback must either have changed its haunts or have been quite exterminated, seeing that its occurrence differs so greatly from the period 1890—1895 to the period 1918—1928, when whaling began off the west coast of Norway. Possibly the enormous traffic of motor vessels and steam-ships during the herring fisheries has frightened this whale away.

No one knows with certainty how far the humpback goes west and southward in its breeding migration in the spring. It is conceivable that breeding takes place at certain places in the Atlantic not far to the south of Ireland. If it went farther south the whaling stations at Cape Finisterre and Gibraltar would presumably have secured some specimens; but so far as I am aware no humpbacks have been found there during the six years in which operations have been carried on.

Summer Migration.

The whaling boat "Skytten"s log-book for 12 seasons shows the following captures of humpbacks in summer:—

1896,	first shot 4/VII,	last shot 2/IX,	total 3	
1898,	— 29/VI,	— 13/VIII,	— 4	
1899,	— 1/VII,	— 3/VII,	— 3	
1900,	— 24/VI,	— 8/VIII,	— 11	
1901,	— 2/VII,	— 29/VII,	— 3	
1902,	— 15/VII,	— 11/VIII,	— 10	
1903,	None.			
1904,	first shot 5/VI,	— 28/VII,	— 4	
1905,	— 13/VII,	— 23/VIII,	— 31	Capture from station at Bear Island
1906,	— 2/VIII,	— 2/VIII,	— 1	
1907,	— 22/VII,	— 22/VII,	— 1	
1908,	— 20/VII,	— 20/VII,	— 1	
			Total 72	humpbacks in 12 summers.
W/b. "Bjørn" in 1906—1907—1908			— 9	
			Total 81	

At the end of June the humpback again appeared in the Arctic, first off Bear Island and later on in the summer off the coast of Finmark, where some humpbacks were caught especially in August; but this was rather in the nature of a rarety.

The migration at Finmark was eastward, but farther from land than the westward migration in winter.

In some years the occurrence at Bear Island was very good, when the whales stopped in the masses of "krill" (Schizopods) around the Bear Island bank, where the cold Polar Stream coming from the N.E. met the warm waters of the Gulf Stream.

In June the temperature of the water around Bear Island near land was about 0° or ÷0.5°. On proceeding westward the water became warmer, and 30—40 nautical miles west of the island the temperature in the sea rose to between +3° and +4°. It was there that the "krill" remained all the summer and attracted humpbacks, fin-backs and blue-whales.

This suitable temperature, +3° to +4°, followed rather closely the edge of the Bear Island bank, and was farthest from Bear Island in the S.W., whence it bent eastward to the S.E. of the island from thence northward.

During the first period, beginning in 1897, when whaling started off Bear Island with tug-boats which towed the whales to Finmark, mainly blue-whales and fin-backs were captured. Humpbacks were only harpooned when no other whales were to be seen.

If we compare the capture of humpbacks off Iceland and that off Bear Island—Finmark, we have the impression that when the humpback has finished calving it proceeds towards Iceland, and follows the edge of teh Polar Current and the western edge of the Gulf Stream northwards past Jan Mayen; then, to

the west of Bear Island, it crosses the narrow arm of the Gulf Stream which goes up to Spitsbergen, finds the supplies of "krill" around Bear Island bank, migrates round the latter, and proceeds to the sea between Spitsbergen — Franz Josef's Land and Novaya Zemlya or towards the edge of the ice in the north-eastern Arctic. The humpback stays there during September-January, and then begins its westward migration along Finmark in February-March.

When the "krill" disappear, which seems to take place at the end of August on the Bear Island bank, the humpback presumably proceeds to the shoals of caplin in the N.E. Arctic and revels amongst them, to judge from its good condition when reaching the coast of Finmark in winter. In August 1905 there were many humpbacks to the N.W. of Bear Island, but over a small area. One boat captured 23 humpbacks there between the 9th and the 23rd. But with that humpback whaling ended for good at Bear Island.

In 1906—1907—1908 two boats captured a total of 12 humpbacks.

During whaling operations in 1905 I had the opportunity of seeing that the humpback is far more intelligent than other species of whale.

It employed two methods of capturing "krill" when the latter was on the surface of the water. One was to lie on its side on the surface and swim round in a circle at great speed, while it lashed the sea into a foam with flukes and tail and so formed a ring of foam. The frightened "krill" gathered together in the circle. This done the humpback dived under the foam-ring and a moment later came up in the centre to fill its open mouth with "krill" and water, after which it lay on its side, closed its mouth, and the catch was completed.

The other method was to go a short distance below the surface of the water, swimming in a ring while at the same time it blew off. The air rose to the surface like a thick wall of air bubbles and these formed the "net". The "krill" saw this wall of air bubles, were frightened into the centre, and then the manoeuvre of the first method was repeated.

When the whale lay on its side and shut its mouth the rifled belly formed an enormous distended bag before it was contracted and the water pressed out between the whalebone-plates.

When one saw that enormous bag, which was many times larger than the real mouth from the gullet to the nose one could understand that the humpback, fin-back, sei-whale and blue-whale have the rifled belly from the point of the chin to the middle of the body, solely in order to be able to take in an enormous quantity of water containing food. With the straight jaws and rather straight palatal region possessed by these 4 whales as compared with the right whales, which have curved jaws and palatal region, there would be little room for water in the mouth, if there was taut, smooth blubber under the chin and belly, as is the case with the right whales, the Greenland whale and the North Cape whale.

The humpback rarely went as far north as Spitsbergen and never eastward

between Spitsbergen and Bear Island, where in the cold southward Polar Current there is no "krill".

In the period from 1905 to 1912, when the whaling at Spitsbergen and Bear Island finished, only a few humpbacks were caught and the stock was very small. The Norwegian Government took up whaling in Finmark in 1918, having 8 whaling boats, 4 at Böle, Söröen, and 4 at Mafjord, Ingø. During two seasons 1 humpback was captured in the week July 14th—21st, 1918, and 2 humpbacks in the week July 21st—27th, 1919, and 1 humpback in the week September 1st—7th of the same year. In 1918 whaling did not commence until the first days of May, so that the winter humpback had then passed Finmark, but in 1919 whaling began in the first days of February, the best time for the winter humpback, but not one was captured and presumably none were seen.

In the summer seasons 1918—1919 4 humpbacks in all were captured by 8 whaling boats, which crossed the old humpback haunts near Finmark and Bear Island.

From the time operations began off the west coast of Norway in 1918, up to the present year, not more than 4 humpbacks have apparently been captured, 2 in July 1926 and 1 in August 1928. Three were shot from boats from Blomvaag Station north of Shetland, and one was brought to one of the Møre Stations in June 1926. On June 9th of this year one humpback was seen out on Storeggen.

The Faroe Islands.

Single humpbacks were captured there in July and August, but they were never taken in large numbers. The figures from Thorsvig Station show the following captures of humpbacks in recent times.

1922, 1 humpback 16/VII, 1923 1 humpback 28/VII, 1924 1 humpback 5/IX, 1925 1 humpback 8/VII, 1 humpback 12/VII, 1 humpback 13/VIII.

In 4 seasons a total of 6 humpbacks by 4 boats.

The Hebrides and Shetland Islands.

According to figures compiled for the Fishery Board of Scotland by D'Arcy Thompson (1928), 31 humpbacks were captured in the period 1908—1914, 1 in May, 2 in June, 15 in July, 11 in August and 2 in September.

From 1920 to 1927 inclusive only 4 humpbacks were captured north of the Shetland Islands, and only 7 were shot west of the Hebrides near St. Kilda.

According to figures given by Risting (1922), 1064 humpbacks were shot off Finmark during the period 1885—1904. Figures are lacking for some seasons, but presumably not more than 1500 humpbacks were captured off Finmark and Bear Island.

Statistics are not available for Iceland, but if we assume that as many

humpbacks were shot off Iceland as off Finmark, e.g. about 1500, and that, off the Faroe Islands, Shetland Islands and Hebrides, at most 300 humpbacks were shot, the total number of humpbacks will be 3300 shot in North European waters.

The stock of humpbacks in the north eastern Atlantic can never have been very large, when such a comparatively small catch as 3300 appears to have entirely exterminated it. By way of comparison it may be mentioned that 3 whaling boats off Porto Alexandra, in Portuguese West Africa, shot a total of 2500 humpbacks in 1909, 1910 and 1911.

If we compare the figures for whaling in the Northern Arctic the general impression we get of the mode of life and migrations of this species of whale is as follows:—

The humpbacks remain in the N.E. Arctic from August until late in the winter. There is a westward migration along Finmark in February, March and April to the breeding places in the Atlantic, from whence there is a northward migration early in summer towards Iceland, and then up towards Bear Island at midsummer for the sake of food and a stay in the N.E. Arctic during the autumn.

In the western migration the adult females are pregnant with large foetuses, in the northern migration in the summer they are accompanied by calves, whilst at the same time there are found small foetuses in the females which are not accompanied by calves.

But of course it is evident that a number of humpbacks do not follow this main migration, but appear at any place and at any time of the year.

It is mainly the adult animals of both sexes that take part in the great breeding and food migration, whilst the younger animals are more erratic in their migrations.

If we compare this state of things with the behaviour of the humpback in other parts of the world, both in the north and the south, it is evident that it is only in the Arctic that the humpback spends the late autumn and winter up in the north, whilst in other parts of the ocean it proceeds towards warmer regions as soon as autumn approaches, whether it be in the northern or southern hemisphere.

Since 1910, when Norwegian whalers began operations all over the globe, we have obtained an excellent general knowledge of the humpback and its migrations.

It everywhere appears that the humpback migrates towards the north and south in order to live on fish, "krill" and copepods, which are abundant there in summer. The humpback then accumulates enormous masses of fat in its blubber, bones and flesh, and on this reserve it lives during its migrations to stay in warmer regions, until it once more proceeds to its feeding places either to the north or to the south.

Greenland.

In 1924 the Tønsberg Whaling Co. sent a floating factory and 3 whaling boats to Davis Strait. According to the records there were caught:—

8 humpbacks in July from the 14th and 10 humpbacks in August from the 2nd, 18 in all.

The Royal Greenland Trading Company have carried on whaling off West Greenland with one whaling boat and one flensing ship. As far as can be seen from the reports, there does not appear to be any abundance of humpbacks in those waters.

Newfoundland.

When modern whaling commenced in those regions, about the year 1900, there were large numbers of humpbacks. Operations were carried on both on the west of Newfoundland and in the Gulf of St. Laurence.

According to Risting (1922) 287 humpbacks were captured in 1903, 281 in 1904. In both years 14 companies took part. In 1905 there were 18 companies at work, but the total catch was only 161 humpbacks. There was a decrease in the capture of blue-whales and fin-backs, but not so great as in the case of humpbacks. In 1915 five humpbacks were caught by 3 boats.

Humpbacks were caught on the east coast of the United States, where the whales went close to the shore and were captured from rowing boats, which worked from small sailing ships. It appears that May was the best month for capture.

The old American sperm whalers carried on the capture of humpbacks from the Bermuda Islands and southward amongst the West Indies in February, March and April.

A few years ago whaling was tried by a Norwegian Company at Grenada. A good stock of humpbacks was found in the winter months, February and March.

If we compare the humpback's migrations towards east America with those towards Finmark, we find that in the case of the former the humpback proceeds in summer northward right up to Disco Island, southward in autumn to warmer regions where it spends the winter, and northward again in spring; whilst in the northern Arctic it spends the summer, autumn and winter in the north, and does not migrate southward until the spring.

This difference can only be ascribed to the greatly varying conditions of current and temperature off the east of America and off north west Europe.

The humpback occurs off the east and west side of North America, on both sides of South America and on both sides of South Africa, and around Australia, especially on the west side.

In every case it proceeds in autumn and winter towards the equator in the hemisphere concerned for the purpose of mating and giving birth to its calf; while

in spring it proceeds northward or southward, according to its stay in the northern or southern hemisphere.

It is difficult to believe that there is any mixture of the stock of humpbacks of the two hemispheres, on account of the feeding conditions. A humpback which goes from the Antarctic towards the Congo, on the West Coast of Africa, in June and July, must return to the Antarctic summer in January and February, because it finds its food there then; it cannot proceed northward to the Arctic, because the season for food will have ended before it arrives there.

It would thus practically be without food for a whole year if it decided to go northward from its breeding grounds in the Gulf of Guinea.

The same conditions prevail in the case of other stocks of humpback in the two hemispheres.

The humpback is the species of whale which least endures being hunted. It is soon exterminated. We have instances of this from the Arctic, Newfoundland, South Africa, South America, South Georgia and South Shetlands.

When the capture of humpbacks on both sides of South Africa began in 1909, there was an extremely rich stock of young whales there. In the course of 3 years over 90 whaling boats operated there.

The results of this far too intense whaling soon showed themselves.

In 1910—1911 the catch off Portuguese West Africa was 250—300 humpbacks per boat, whilst in 1925 the result was 17 humpbacks from 3 boats or 5—6 humpbacks per boat.

At the end of the war, whaling was again taken up off the French Congo. No operations had been carried on in those waters during the whole of the war and for some years after, so that the humpback had been left in peace.

In 1923 the average catch per boat was 137 humpbacks, but in 1925 the average catch decreased to 60 humpbacks.

Around the southern end of South Africa from 1910 and onwards mainly humpbacks were captured. This species of whale has now become rare, so blue-whales, fin-backs and sei-whales are captured instead.

When whaling began at South Georgia and South Shetland there was an extremely rich stock of humpbacks. Now the latter are rare in those regions. The only place where the humpback plays any part in whaling is off West Australia, where it goes from the Antarctic to breed.

In March 1926 large numbers of humpbacks were observed off the Baleny Islands.

The reason why the humpback succumbs so quickly to whaling as compared with other species is no doubt that it is a species of whale with far more definite habits of life and haunts than other whales, so that when whaling begins at any one place or is carried on continuously the stock is so reduced that breeding ceases.

But no whaling has been more destructive in the case of the humpback than that which has been carried on at the actual breeding grounds in the Tropics, and if it continues the humpback will certainly be exterminated.

As humpbacks are not captured in the Arctic at the present time, there is still hope that the remaining animals may breed, but it will take a very long time before the stock is restored. If the Arctic humpback could be preserved, as it is at South Georgia and South Shetland, such a measure would undoubtedly help to bring about the revival of the stock.

The Finback.

Finmark — Bear Island — Spitsbergen.

The whaling log-books of M. A. Ingebrigtsen show the following figures of finbacks caught in winter off Finmark:—

1896,	frst shot	16/III,	last shot	23/IV,	total	10
1898,	—	24/III,	—	26/IV,	—	6
1899,	—	15/III,	—	20/IV,	—	9
1900,	—	26/III,	—	7/IV,	—	5
1901,	—	18/II,	—	24/IV,	—	10
1902,	—	18/III,	—	14/IV,	—	4
1903,	—	4/IV,	—	4/IV,	—	1
					Total	45

The above figures show that the finback was present off the coast of Finmark about March 15th—20th, and again disappeared in the latter half of April. the whale came from the N. and N.E., and remained off the coast from Varanger Fjord to Sørøen, rarely less than 20 miles from the shore. There it feasted on the shoals of caplin, which come at that time from the Arctic Ocean to spawn near land.

At that time of year the finback was very fat and the stock consisted of large animals of both sexes.

Unfortunately no exact measurements and descriptions are available of the whales captured off Finmark, but it is known that the adult females were pregnant with fully grown foetuses. At the same time newly born calves were found.

Professor Collett (1912) states that in the month of March one foetus 14′ long and another 78 mm. long were found on the same day. He further states that newly born calves 20 feet in length were observed in April and June with their mothers.

When the finback disappeared at the end of April the bulk of the whales presumably proceeded westward. In some years finbacks were found off Senjen in May. In 1898 5 were shot from one boat, between the 2nd and 27th of May.

The whale stayed where the deep sea from the west meets the shallow bank

which runs thence in the direction of Bear Island. The finback cannot have gone far westward because it appeared off Bear Island as early as May.

In	1896	the	first	summer	whale	was	shot	1/VI,	24 n. m. N. of Ingö.
-	1898	—	—	—				3/VI,	off Ingö.
-	1899	—	—	—				2/VI,	near the ice S.W. of Ingö.
-	1900	—	—	—				23/V,	— — —
-	1901	—	—	—				13/VI,	off Ingö.
-	1902	—	—	—				19/VI,	W. of Bear Island
-	1903	—	—	—				1/VII,	S.S.O. - — — 30 n. m.
-	1904	—	—	—				8/VI,	N.W. - — — 50 —
-	1905	—	—	—				11/VII,	W. - — — 40 —
-	1906	—	—	—				21/VI,	W. - — — 40 —
-	1907	—	—	—				3/VI,	W. - — — 40 —
-	1908	—	—	—				29/VI,	W. - — — 40 —

The above data show that the finback was off Finmark at the beginning of June. It then migrated eastward until the end of August, and in one year until September 18th, (1896) when the last whale was shot off Ingö.

If there was a good supply of "krill" or copepods the whale might remain for long periods off the coast at a distance of 30—40 nautical miles from shore, but rarely nearer. In the transition layers between the north border of the Gulf Stream and the cold Polar Stream, which lay to the N.N.W. of Fruholmen, about 120—140 nautical miles from land, there was often a good eastward migration of finbacks; and there was a large supply of "krill" there each year.

The finbacks which came in June were thin but quickly grew fatter in the course of the summer, so that they were very fat in August.

When whaling finished off Finmark in 1904 there had been several bad years off the coast, and few finbacks had been seen. Most companies, therefore, carried on operations off Bear Island in 1903—1904.

When in 1918 the Norwegian Government took up whaling off Finmark, the stock was found to be very large, so that from the station of Böle at Söröen 183 finbacks were captured from June 8th—August 24th. So many had never been captured off Finmark in any corresponding period. In 1919 the catch was again smaller, only 98 finbacks being caught from the said station by 4 boats. In 1920 the catch diminished further, only 44 finbacks being captured. Since that year whaling operations have not been conducted off Finmark.

Bear Island.

The finback sometimes appeared there at the beginning of June, sometimes as early as May. In 1900 one was shot on May 4th E.S.E. of Bear Island, 40 nautical miles from land. In good "krill" years the finback remained throughout June, July and August along the whole of the Bear Island bank from east

to N.W. of the same and continued upwards towards Spitsbergen. It there lived upon "krill", and in certain years at the end of August upon caplin. It only appeared east of Bear Island bank, never south or west of Bear Island. The occurrence of finbacks in those waters varied greatly. Some years were good, but many were bad. When whaling operations ceased there in 1908 one had the uncomfortable impression, that the stock had been greatly reduced.

When the whales disappeared at the end of August, the bulk of them proceeded eastward to the north-eastern Arctic.

Spitsbergen.

The fin-back arrived here simultaneously with the whales at Bear Island. Everything goes to show that the Spitsbergen whale migrated from the S.W. along the edge of the ice, from whence it proceeded to the Spitsbergen bank or to the transition layers between the Gulf Stream and the cold Polar Stream which runs around South Cape and follows the west coast northwards about 30—40 nautical miles from land.

In 1920 the writer was whaling at Spitsbergen. There we found in July a small stock of finbacks N.W. of Foreland, about 80 nautical miles from land, in the western ice. Later investigations have shown that in some years the stock would yield profitable whaling, whereas in other years the stock is quite insignificant.

The cause of the great fluctuations in the occurrence of finbacks at Bear Island and Spitsbergen in our time must be sought in the great variations in the supply of food, i.e. "krill" and copepods.

The finbacks at Bear Island and Spitsbergen were as a rule large, fat animals as compared with those captured in more southern regions in the Norwegian Sea and Atlantic Ocean.

In addition to the finbacks, which migrated eastwards to the Northeastern Arctic in order to spend the winter, a considerable number of whales doubtless proceeded towards the Norwegian Sea.

The West Coast of Norway.

The first	winter	finback	was	shot	in	1922, 25/I off Sletringen.
—	—	—	—			1923, 11/II - Ona Fyr.
—	—	—	—			1924, 17/I - Sletringen.
—	—	—	—			1925, 25/I - Hustadviken.
—	—	—	—			1926, 17/I - —
—	—	—	—			1927, 16/I - Storholmen.
—	—	—	—			1928, 20/I - Hustadviken.

The dates for 1922—1923—1924 are from Vingvaagen whaling station, the others from Aukra whaling station.

The Norwegian Government commenced operations in 1918 from 3 stations on the west coast. Whaling has since been carried on there, and there are now 4 stations each with 3 whaling boats at work.

From the exact tables of capture which are available for 10 years, we obtain a comparatively good knowledge of the occurrence and mode of life of the finback in the S.E. Norwegian Sea.

As shown by the above data, the fin-back approaches land off the coast of South Tröndelag and Möre about January 20th. It reaches the coast off Fröya and Smöla, and follows it westward in Februar and March, and disappears westward towards "Tampen" and Shetland in the first days of April.

During its main migration the whale may stop for a considerable time at any place where it finds a good supply of "krill". In some years it may happen that before proceeding to "Tampen" it follows the coast down to Utsira.

In good "krill" years the whale lives entirely upon this food. In 1924 there was an enormous amount of "krill" off the coast of Möre from the end of January to the beginning of April. From Vingvaagen whaling station 3 boats shot 85 finbacks between January 17th and April 12th, and only one whale had large herring in its stomach.

But if there are small quantities of "krill" in winter, and this has been the case since 1925, the finback eats large herring. This, however, is no sufficient reason for calling the fin-back "the herring whale" as Zoologists commonly do. "Krill" and copepods are the main nourishment of the finback for the greater part of the year. The humpback also eats herring, if no other food is to be had.

The "grampus" (or whale-killer) is the real herring whale.

Therefore, when during the large herring and spring herring fisheries there are notices in the papers about "Shoals of herring and whales" having been observed, in nine cases out of ten it is the "grampus" and not the finback. I have had good opportunities of proving this during 7 years' whaling off the coast of Möre during the large herring fishery in January, February and March.

In April and May a considerable number of finbacks stay around the edge of the bank at "Tampen" in the northern part of the North Sea and westward past the Shetland Islands. In April the copepods and summer "krill" begin to congregate in those waters and provide nourishment for the finback.

The finbacks which have stayed off the coast of Möre and Sogn and Fjordane county, in January, February and March, do not appear to proceed far westward in the Atlantic, since at the end of May they again appear at "Storeggen" off Möre. In June, July and August they occur along the entire edge of the bank, which begins at Storeggen and extends N.E. off the coast at a distance of 60 to 80 n.m.

In August the bulk of the finbacks seem to disappear from the above-mentioned regions to the north and north-east. Possibly a number of these whales return south-westward again, since captures have been made from Hestnes Station

in September. In some years this south-westward going stock of finbacks has been observed off Blomvaag whaling station in September and October.

During its summer migration off the west coast of Norway the finback lives exclusively upon "krill", very rarely on copepods and never upon herring, although shoals of herring have been observed on the whaling ground during the summer operations.

Simultaneously with the summer catch of finbacks off the west coast of Norway the best catches of that species of whale are made from the stations at the Faroe Islands, North Shetland and the Hebrides. When operations were carried on off Iceland the best season for the finback was also in the summer months.

When whaling operations were commenced from the permanent Station at Corcubion in northern Spain and farther south on the coast of Portugal the main capture of finbacks took place from May to October.

It will be seen from the above that the finback occurs in greatest numbers in the summer (May— September) over the enormous region which extends from Spitsbergen in the north to the coast of Portugal in the south.

The stock of finbacks in the eastern Atlantic, the Norwegian Sea and the Arctic Ocean must therefore be quite large.

The finback is caught off Gibraltar nearly the whole year round, but the winter months are the best. As it appears that the finback occurs simultaneously as far north as Finmark, off the west coast of Norway, and off Gibraltar in winter, we may conclude that it does not make definite breeding migrations like the blue-whale, the humpback and the sei-whale, but gives birth to its calves in any part of the sea as soon as the foetuses are fully grown.

If, therefore, in certain whaling regions of the Atlantic, the Norwegian Sea and the Arctic Ocean, definite migrations of finbacks are observed, e.g. a westward migration off the west coast of Norway in winter and a north-easterly migration in summer, the cause of these must be the migration of the whale from one feeding-ground to another.

The finback occurs in summer and winter on the west side of the Atlantic along the east coast of America and right up to Disco Island. In recent years operation shave been carried on off the coast of Labrador, where as far as is known the best finback season has been the late summer and autumn. In winter and far into the spring the ice stretches southward past Newfoundland, whilst at the same time it covers the greater part of Davis Strait. It is therefore natural that at that season of the year the finback migrates southward to warmer waters along the east side of America and returns to the north as summer approaches.

The conditions of temperature in the sea along the east side of America and in Davis Strait differ, of course, so much from those along the west coast of Europe, that there must necessarily be a difference between the migrations and mode of life of the finback in those two areas. The conditions in North American

waters resemble those prevailing in the Antarctic, where we are practically certain that most species of whales migrate towards warmer or more temperate waters in the winter of the southern hemisphere, and again return to the ice barrier around the Antarctic in the spring and summer.

On both sides of South Africa the finback is captured in the winter of the southern hemisphere. It does not go so far north as the humpback. On the east side of South America no occurrence of the finback has been observed. On the other hand this whale is quite numerous along the coast of Chile, in the Pacific, where it is to be found all the year round, though in largest numbers in December, March and April.

Off Equador and Peru the finback is found from June to November.

In the northern Pacific the finback is caught off Japan, Korea and Kamchatka. In the last-named regions 236 whales were shot in 1926 from June 10th to October 24th from 5 boats. The best season was in August—September.

Off the Aleuter Islands at the entrance to the Bering Sea and along the coast of British Columbia and the United States to about 30° N. finbacks have been caught for nearly 20 years. It appears that the finback does not proceed farther south than 30° N., since it has not been caught by the expeditions which for several years have worked off the coast of lower California. I carried on whaling operations from Magdalena Bay in 1913—1914, but saw no finbacks. This southern limit for the distribution of the finback in the eastern Pacific also applies to the eastern Atlantic, where no stocks of this whale have been found south of 30° N.

In the waters around Australia and New Zealand the experiments made in the years 1912—1914 showed that the number of finbacks there is very small.

The finback remains in all parts of the Antarctic during the southern summer and on into the autumn. Whether it is as numerous in those waters as in the area South Shetlands—Georgia, South Orkney and South Sandwich, would seem to be doubtful.

The Blue-whale.

Northern Hemisphere.

Unlike the finback and humpback which spend the winter in the N.E. Arctic, the Norwegian Sea and off the coasts of Spain and Portugal, the blue-whale disappeared from those waters in September and migrated to a more southern winter resort in the Atlantic.

At the end of March and the beginning of April the blue-whale appeared off N.W. Iceland on its way to the Arctic in April and May. It migrated also north-east and northward past the west coast of Ireland and the Hebrides, and past the Faroes, and disappeared towards the Arctic Ocean.

The first blue-whale was found there in May on the Bear Island bank and later on in June and July off East Finmark.

On the basis of observations and statistics taken at stations in Iceland, the Faroes, Hebrides and Ireland, we may conclude that the blue-whale makes the following migrations in spring.

One stock comes from the S.W. and follows the transition between the Polar Stream and the warmer waters on the east side of Greenland, proceeds in these transition waters past N.W. Iceland, continues north east past Jan Mayen along the edge of the ice, then on towards Spitsbergen until it comes to the Spitsbergen bank, then southward towards Bear Island along the Bear Island bank, if the ice presents no obstacle, round Bear Island bank and further eastward, till it reaches East Finmark, where it appears in June and August.

Another stock comes in April, May and June past Ireland, the Hebrides and Faroes; it proceeds towards Iceland and mixes with the stock migrating there.

When whaling operations were commenced off Finmark about the year 1870 by Svend Foyn, it was mostly blue-whale that were shot during the first years in the Varanger Fjord district.

The number of whaling boats rapidly increased in Finmark; before many years had elapsed the blue-whale, which at first had been the main catch, became a rarity off Finmark.

According to Risting (1922):—

In	1885	34	blue-whales	were	shot	from	31	boats
-	1886	114	—	—	—	—	35	—
-	1887	55	—	—	—	—	30	—
-	1888	68	—	—	—	—	33	—
-	1889	14	—	—	—	—	31	—
-	1890	22	—	—	—	—	27	—
-	1896	58	—	—	—	—	27	—
-	1897	94	—	—	—	—	23	—
-	1898	24	—	—	—	—	23	—

Of the last-named 24 whales 11 were shot off Bear Island by the whaler M. A. Ingebrigtsen who since 1897 had begun summer operations there with a tug-boat which towed the captured whales to Finmark.

In 1899, 47 blue-whales were shot from 23 boats, 14 of these whales being from Bear Island; in 1900 12 blue-whales from 23 boats; in 1901 11 blue-whales from 20 boats; in 1902 58 blue-whales from 20 boats, 37 of these whales being from Bear Island; in 1903 126 blue-whales from 17 boats, 115 being from Bear Island; and in 1904 373 blue-whales from 18 boats, 138 being from the west of Spitsbergen; 233 from off Bear Island and only 2 from off Finmark.

At the same time that the blue-whale was being caught off Finmark, Bear Island and Spitsbergen, it was vigorously hunted, from the year 1890 onward, off Iceland and to a lesser degree from the Faroe Islands; and after 1906 from the Hebrides and Ireland as well.

The last important whaling year at Bear Island and Spitsbergen was in 1904. After that the catch of blue-whales decreased from year to year, until it ceased in 1912. Operations continued off Iceland until 1915, when 9 blue-whales were captured from 4 boats.

When operations commenced off the Hebrides in 1906 and off Ireland in 1908 a considerable number of blue-whales were captured in those waters.

Since the cessation of whaling off the Hebrides between 1914 and 1920, the stock of blue-whales appears to have increased in those waters. Since 1918 only a few animals have been shot off the west coast of Norway. Three were shot in 1924, the greatest number in a single season.

Last year one female blue-whale 84 feet long with a foetus 8 feet long, was taken into Aukra whaling station on June 9th.

When August comes the blue-whale begins its migration from the Northern Arctic Ocean towards the S.W., and then presumably follows the same route southward as that which it takes northward in spring. The blue-whale was found to be rather thin on its spring migration towards the north, but increased well in weight during the summer after having feasted on "krill".

Of the females which were captured off Bear Island and Spitsbergen, the majority were pregnant with foetuses 6—12 feet in length or were accompanied by calves which had been born in the tropics during the winter. The animals which remained in the northern Arctic Ocean were all fully grown specimens, 75—85 feet in length, whereas off the Hebrides, according to D'Arcy Thompson (1928), the average blue-whale has a length of about 70 feet.

Off the coasts of Spain and Portugal the blue-whale is rare.

A considerable number of blue-whales were captured on the east coast of America off New Foundland, where operations began in 1902. The blue whale stays in Davis Strait during the summer, and we may therefore assume that its migrations off the east coast of America are similar to its movements off the west coast of Europe, i.e. the whale goes to the north in spring, stays there in summer, and proceeds southward to warmer seas in the autumn.

The fact that the occurrence of blue-whales varied greatly from one year to another in the North Eastern Atlantic and in the Arctic Ocean might possibly have had some connection with the northward migration of blue-whales off the east coast of America. When they went northward and encountered the ice which in spring lies between Cape Farewell and the coast of Labrador it is quite conceivable that, instead of proceeding northward into Davis Strait, these animals went to the N.E. along the edge of the ice on the east side of Greenland. The circumstance that the blue-whale appeared off Iceland as early as March appears to confirm this assumption.

Hjort (1902, page 136) mentions that American harpoons have been found in blue-whales shot off Finmark.

The Tönsberg Whaling Company shot, in 1924, 33 blue-whales in Davis Strait in July, from the 11th onward, and only 1 blue-whale in August, on the 7th of that month, between 67° and 69° N. and 53°—56° W.

The stock of blue-whales does not appear to be very large in those waters.

No one knows with certainty how far south in the northern Atlantic the blue-whale stays in winter. At the end of March 1911 I saw 12 blue-whales between the Cape Verde Islands and Africa in the course of an afternoon. At Cape Blanco on the west coast of Africa in 1925, 3 were shot in December, 2 in January, and 1 in February.

If we proceed to the northern Pacific we find along the west coast of America a migration of blue-whales similar to that in the northern Atlantic.

In 1913 I carried on whaling operations from Magdalena Bay, in lower California. At the end of October the blue-whale came from the north and proceeded southward along the shore. Then in April, May and June it came northward again.

When the blue-whale went southward it was in good condition, but on its northward journey it was thin and wretched.

According to the statistics of the Norwegian Whalers' Association for 1925—1926 the Mexico whaling company made the following catch of blue-whales: 4 in October, 1 in November 1925, 3 in February, 6 in March, 33 in April, 46 in May, 20 in June 1926, a total of 113 blue-whales.

Whaling operations have been carried on along the entire west coast of North America as far as the Bering Sea. The blue-whale occurs there in the summer and autumn off the coastal banks where "krill" is present in great quantities.

On the west side of the Pacific we find the same migrations of blue-whales as on the east side; but the western migration of the blue-whale does not appear to go so far north as that on the east side.

The "Vega" expedition of 1925 to Kamchatka, from June 9th to October 6th, with 4 whaling boats, captured 2 blue-whales in September and 3 in October.

According to Risting (1922): 52 blue-whales were shot in 1915, 70 in 1916, 53 in 1917 and 25 in 1918 at the Japanese whaling stations.

It therefore appears that the stock of blue-whales along the east coast of Asia is not nearly as large as that on the west coast of North America.

The Southern Hemisphere.

The blue-whale is captured on both sides of South Africa from April to October, August and September being the best months. On the west coast of Africa it goes northward to about 10° S. where it turns south in August.

The same movements are found on the east coast of Africa.

The blue-whale off South Africa comes from the Southern Antarctic, where it spends the summer before proceeding northward to warmer waters to give

birth to its calves; it returns again to the Antarctic towards the spring. These migrations closely correspond to those of the blue-whale in the waters of the northern hemisphere.

The farther north the blue-whale travels along the coast of Africa the thinner and more wretched it becomes. Whales captured very far north can almost be regarded as corpses and are not worth catching. Whales should not be captured north of 30° S. and whaling operations have automatically ceased there, as being quite unprofitable.

No stock of blue-whales has been found off the east coast of South America. On the other hand this whale has been, and is still, caught on the west coasts of Chile, Peru and Equador.

Off the coast of Chile operations take place from Corral Station, 41° S. where 3 whaling boats caught 76 blue-whales from January to June in 1925.

Off the coast of Peru, from August 1925 to April 1926, 5 whaling boats shot 274 blue-whales, 247 of which were caught in December, January, February and March. The best month was March, when 88 were shot.

The months of August, September, October and November only yielded 16.

The fact that the occurrence of blue-whales off Peru is greatest in the southern summer, when the blue-whale of the southern hemisphere is most numerous in the Antarctic, would appear to indicate, that this blue-whale must belong to the stock along the Pacific side of North America which in October-November travels southward along California.

From May to December in 1926, 68 blue-whales were caught off the coast of Equador by 4 boats. September was the worst month.

Operations off Peru and Equador have now ceased, because the whales caught in those tropical waters were far too thin to provide a remunerative business.

As far as I remember the blue-whale yielded 20—30 barrels of oil, whilst the yield of the blue-whale in the Antarctic during the southern summer is, on an average, 80—100 barrels.

These facts clearly show that the capture of whales in the tropical region 30° on either side of the Equator should not be allowed.

In the southern summer the blue-whale is found in enormous numbers in the waters between the South Shetlands, South Georgia, the South Orkneys and the Sandwich Islands along the edge of the ice in Weddel Sea and far into the ice. Shackleton saw the blue-whale right up to the Ice Barrier.

The result of the latest operations in the Ross Sea has shown that a large number of blue-whales have their feeding grounds there in the southern summer.

It is quite unknown whence this large stock of blue-whales migrate in the southern winter.

It appears from the catch on the west coast of Australia that the blue-whale

is very scarce. In 1926, at the Norwegian Bay Station 23° S., 1 was shot in September and 4 in October by 3 boats.

When in 1912—1913 whaling was tried round Australia (with the exception of the north coast), Tasmania and New Zealand, it was found that the blue-whale did not occur in those waters in any appreciable numbers.

A small stock of blue-whales has been found at Kerguelen.

The Sei-whale.

Northern Hemisphere.

Like the blue-whale the sei-whale stays in the southern part of the north Atlantic during the winter. Off Cape Blanco, 21° N. on the west coast of Africa, 10 whales of this species were shot from 4 whaling boats in December 1924; 10 in January and 18 in February 1925. In the same season not more than 7 Sei-whales were caught off Spain and Portugal, all from Corcubion in north Spain; 3 in April, 3 in May and 1 in July. These small numbers show that during its migration northward the sei-whale does not keep to the coast of Spain and Portugal but proceeds so far out to sea that whaling boats from the stations on this coast do not get it.

The numbers of this species of whale off the west coast of Ireland are also small. There are rather more of them off the Hebrides, but it is not until we reach the N.W. of the Shetlands that they are sufficiently numerous, in April and May, to be regarded as abundant. From the bank off the N.W. of the Shetlands these whales proceed along the latter towards "Tampen" in April and May and appear off the coast of Møre about the middle of April. The migration then increases until the end of May. If the supply of copepods off the coast of Møre is favourable the whales may remain there throughout the summer. They then feed on red copepods and "krill". The best year for this species in those waters was 1923 when they appeared in the middle of April and remained until the end of July, 215 being caught by 3 boats from Vingvaagen whaling station.

Throughout the summer of 1923 the supply of "krill" was extremely large along the Storeggen and on the coastal bank.

If, when they arrive in April and May, the sei-whales do not find good feeding conditions as regards copepods and "krill", the majority of them proceed northward and north-eastward, and appear off Finmark at the beginning of July. If the feeding conditions off Finmark are favourable they remain there until the end of August.

The sei-whale occurs very scantily off Bear Island and Spitsbergen. There were occasional visits of these whales in June, but they quickly disappeared. On June 27th, 1920, I shot a female which was accompanied by a large calf, in 79° N., 100 nautical miles west of Foreland. The shoal, which consisted of 6 whales, was close to the edge of the ice. As the appearance of these whales so far north is very

rare it may safely be said that the majority of this species in the north eastern part of the Atlantic and the Norwegian Sea do not proceed beyond 72° N.

During operations off Finmark from 1880 to 1904 there were great fluctuations in the numbers of these whales from year to year. As their migration to the north is made exclusively in order to find food, it is natural that when they found good supplies of food farther south, e. g. off the coast of Møre, they remained there throughout the summer, only a few proceeding as far north as Finmark.

In some years a large number were captured off the Faroe Islands during the summer, whilst in other years not one was shot. Their presence off the Faroes, as off Finmark, is entirely dependent upon the feeding conditions.

The sei-whale is scarce off Iceland. The greatest number captured was 20 whales by 30 boats in the 1900 season.

These whales have proved to be more regular visitants of the coast of Møre. They appear between the 5th and 15th of April. If the feeding conditions are favourable the numbers greatly increase in the course of a single week, culminating at the end of May. In years of favourable conditions they remain in those waters throughout the summer, but in unfavourable years they disappear at the end of May and only appear at rare intervals during the rest of the summer.

The sei-whale, more than any other species, is sensitive to weather conditions. A northerly cold wind with snow in April and May will completely drive them from the Møre whaling ground.

During those summers when they have remained longest in the Møre waters the prevailing winds have been from S.W. to W. with rain and high temperatures.

When these whales arrive off Møre in April the adult females are accompanied by calves born in the southern regions, presumably in February-March.

At the same time females are captured containing foetuses from 10—40 cm. in length.

The sei-whales are very lean when they arrive in April and on an average do not yield more than 10 barrels of oil; but those caught in July have put on weight and yield about 20 barrels.

The blue-whale, fin-back and humpback turn over, often with part of the head above water, when feeding.

The sei-whale, on the contrary, "skims" the food. It swims at great speed through the swarms of copepods, with half open mouth, its head above water to just behind the nostrils. The copepods rush in with the water and are filtered from the water by the whale-bone plates. When a suitable mouthful of copepods has been taken the whale dives, shuts its mouth and swallows the food. It is especially in the evening and early in the morning, when the copepods are most at the surface, that "skimming" takes place.

Unlike the three above-mentioned species of whales, which move very regularly, first under the water and then up to the surface in order to blow off, the

sei-whales remain high in the water; thus they can be traced for a long distance by the eddies which the strokes of the tail make on the surface.

When these whales have no copepods they are often so shy and difficult to approach within shooting range, that they may be chased all day without being shot.

Off the North Shetlands a considerable number are caught along the entire edge of the bank and to the north of the same from April to July. The catch decreases in August.

The number off Iceland is very small and of no importance for whaling.

Along the east coast of America and Newfoundland, the sei-whale does not occur. In RISTING's book (1922), the catch in those waters is specified as regards the number and species of whale, and the sei-whale is not mentioned.

It is found on the Pacific coast of N. America, but in no great numbers.

From Magdalena Bay, Lower California, 20 were captured in 1924—1925, by 4 whaling boats in February and March.

On the east coast of Asia the sei-whale is so numerous that it is important for whaling purposes. According to the statistics given by RISTING (1922) 717 were shot in 1915, 393 in 1916, 579 in 1917 and 728 in 1918.

On the coast of Kamchatka the "Vega" expedition from Sandefjord shot in 1925, 6 sei-whales, 4 in September and 2 in October.

On the east coast of South America, off Patagonia and the Falkland Islands, a large number of these whales has been found in the southern summer and part of the autumn.

But operations were abandoned as being entirely unremunerative, the whales being too small and lean.

At South Georgia the sei-whales may appear in the autumn, sometimes in large numbers; but there, too, their capture is not remunerative.

At South Shetlands this whale is rare, which is natural in view of the polar character of that region.

To the west of South America, off the coast of Chile, this whale is not found. Farther north off the coast of Peru and Equador whaling expeditions have found a small number of sei-whales. Off the coast of Peru, in 1925—1926, 6 boats captured 17 between July 25th and March 26th. In the same season 4 boats caught 15 off the coast of Equador from May to November.

It is doubtful whether these whales were true sei-whales because the Bryde-whale (*Balaenoptera brydei*) also occurs in those waters and can easily be mistaken for the sei-whale.

In September 1914 I shot a Bryde-whale at La Plata Island north of the Bay of Guayaquil.

The sei-whale is found in large numbers on both sides of South Africa in the southern winter. But the whales captured, especially farthest to the north,

are extremely lean and almost like corpses, so, of course, they ought not to be shot.

This species of whale does not, apparently, occur off the coast of Australia.

The regions where the sei-whales afford opportunities of remunerative whaling are the Norwegian Sea off the Shetlands, the Faroes and the west coast of Norway. In the latter region, it is especially the flesh of the sei-whale that renders the catch remunerative, as each whale yields from 1000 to 2000 kilos of meat, and this meat finds a ready sale as a popular form of food. Without this addition to the value of the sei-whale, its capture would hardly be worth while, as the oil and guano produced would not pay the working expenses.

Concluding Remarks.

If we follow the course of modern whaling from its initiation by Svend Foyn in Finmark about the year 1870 until the present time when its operations extend to almost all the waters of the globe, we see that with few exceptions such operations sooner or later reduced the stocks of whales in the various regions so greatly that whaling had to be abandoned as unremunerative.

From about the year 1880 onward, a number of whaling stations were established along the coast of Finmark, and the number of boats rapidly increased from 4 in 1880 to 34 in 1885. The results were soon apparent. After about the year 1900 whaling at most of the Finmark stations ceased to pay and steadily declined. In 1903 most of the companies had to start operations at Bear Island and tow the whales to Finmark with their tug-boats. In 1905 operations were commenced at Bear Island and Spitsbergen, but there too the work was not of long duration. Too many boats destroyed the chances and in 1912 these waters were entirely abandoned.

Subsequent attempts were made at Spitsbergen in 1920 and 1925—1926 with ruinous results.

Operations commenced off Iceland about the year 1890 with 8 whaling boats. The catch was good and the number of boats increased to 30 in 1902. There was then a steady decline in the catch and one station after another was closed.

The last whaling year at Iceland was 1915, when 54 whales were shot from 4 boats.

At the Faroes, where operations commenced in 1895, the results were similar to those in Finmark and Iceland. As the number of boats increased the catch per boat greatly decreased and one station after another closed.

During the war, operations were not carried on in those waters to any great extent, so that the whales were left in peace; this was undoubtedly good for the stock, for the catch off the Faroes with fewer boats, as compared with the number used before the war, yielded reasonable profits.

Whaling commenced off Newfoundland about the year 1900. A large number of whales was captured per boat. But then more and more boats appeared; — in 1905 there were 18 companies and presumably about 40—50 boats. That was the end. The catch declined year after year, and most of the stations had to be closed.

One company from Newfoundland moved in 1907 to Vancouver Island on the Pacific coast. Operations commenced on the west coast of America and in the first years the results were amazing. But the number of boats quickly increased along the entire coast from Alaska down to Mexico and the result was the same in the Atlantic and the Arctic. There was a great reduction in the stock of whales, and one station after another had to close.

In 1908—1909 operations commenced on both sides of South Africa with excellent results. In the first years practically humpbacks only were shot. Now that species of whale is rare in those regions, as compared with the first whaling period.

Today the number of whaling boats off Africa is greatly reduced as compared with 1912; but operations are now based upon blue-whales and fin-backs, and to a lesser extent upon sei-whales.

In 1920 whaling commenced in the Strait of Gibraltar with two boats; and at first the results were very good. More than 500 finbacks were caught per boat per season, and a number of larger, more efficient whale-boats were brought into action. In the year 1926 four boats caught 259 whales, i. e. an average of 65 whales per boat. In 1927 whaling came to an end in these waters.

Risting in his book (1922), in which the above information will be found, gives details of the development of whaling from its commencement off Finmark to the present day.

All these details clearly show the fate of the stock of whales when operations are carried on quite freely without restrictions.

The great extension of whaling in the Antarctic will undoubtedly, in spite of the vast tracts of ocean and the apparently enormous numbers of whales, produce in the course of some years the same results as in all other waters, namely a decreasing stock of whales from year to year.

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HYDROGRAPHICAL INVESTIGATIONS DURING THE "MICHAEL SARS" EXPEDITION 1924

By

ERIK MARTENS

The hydrographic observations made during Professor HJORT's expedition to Davis' Strait in the summer of 1924, comprise three different areas of the sea (see Fig. 1). Both on the outward and homeward trips sections were made between the western coast of Norway and the Faroe Islands. On the outward trip a section

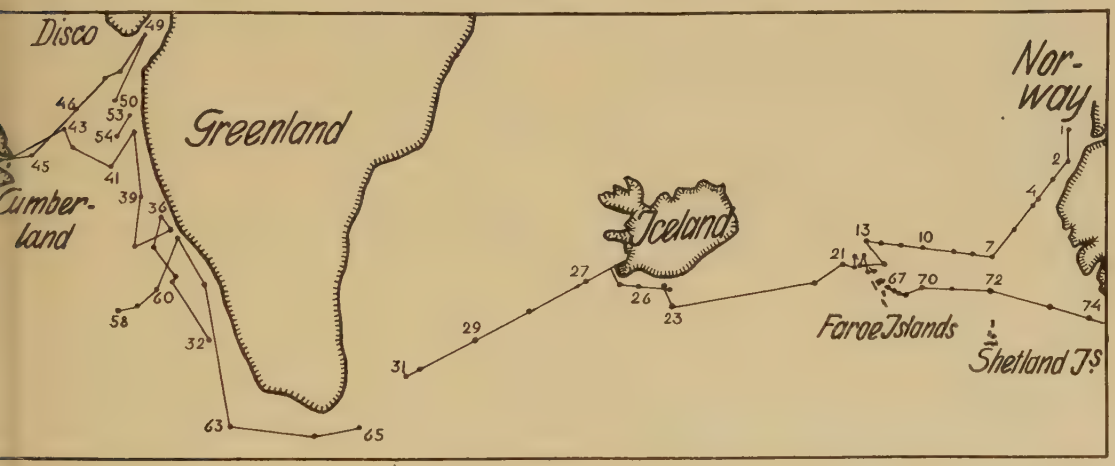
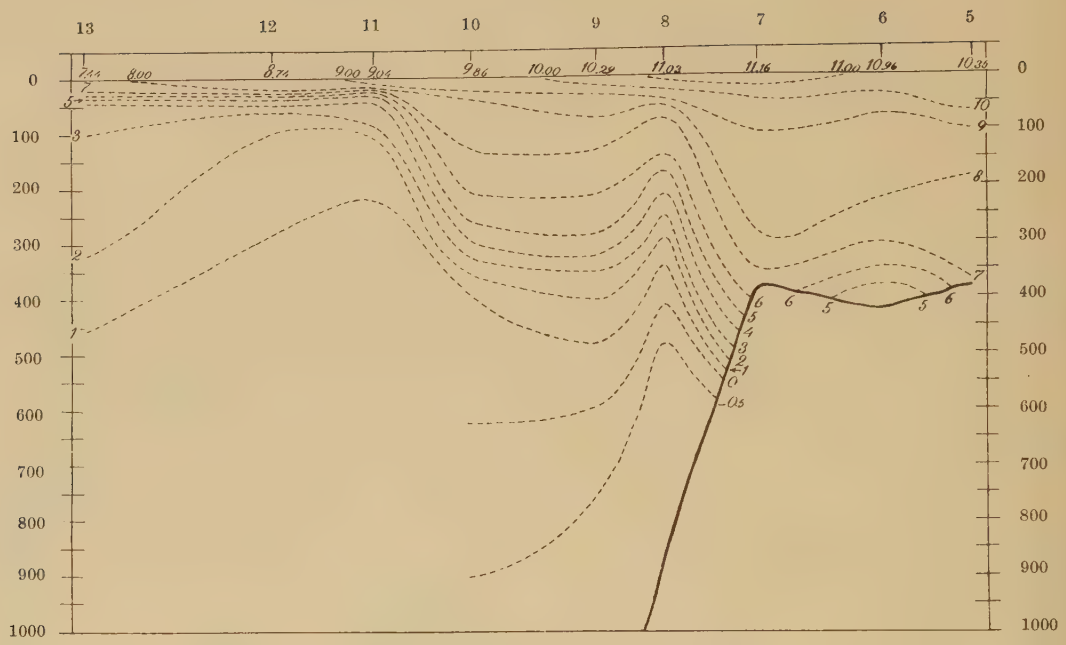


Fig. 1.

was made between Iceland and Cape Farvel comprising five stations. And, finally in the special exploration area of the expedition, Davis' Strait, a number of different sections were made in different directions and at various places. In the following is given a survey of the hydrography of the different areas based on the material handed over to me in form of tables and diagrams by Professor HJORT.

The first section (Figs. 2, 3, 4, 5) comprises the stations from the mouth of the Norwegian channel to a position 2 degrees north of the Faroe Islands. These stations are not in line. The first three stations (Nos. 5, 6 and 7) are situated along the continental slope, across the mouth of the Norwegian Channel, whereupon the section turns into a more north-westerly direction. The salinity-diagram indicates that Atlantic water (Salinity above 35 $^{0}/_{00}$) was found on all stations with the exception of one (Station 12). North of the Faroe Islands the Atlantic water forms an intermediate layer between the depths of 100 and 350 metres. It seems that this water has passed the threshold between the Faroe Islands and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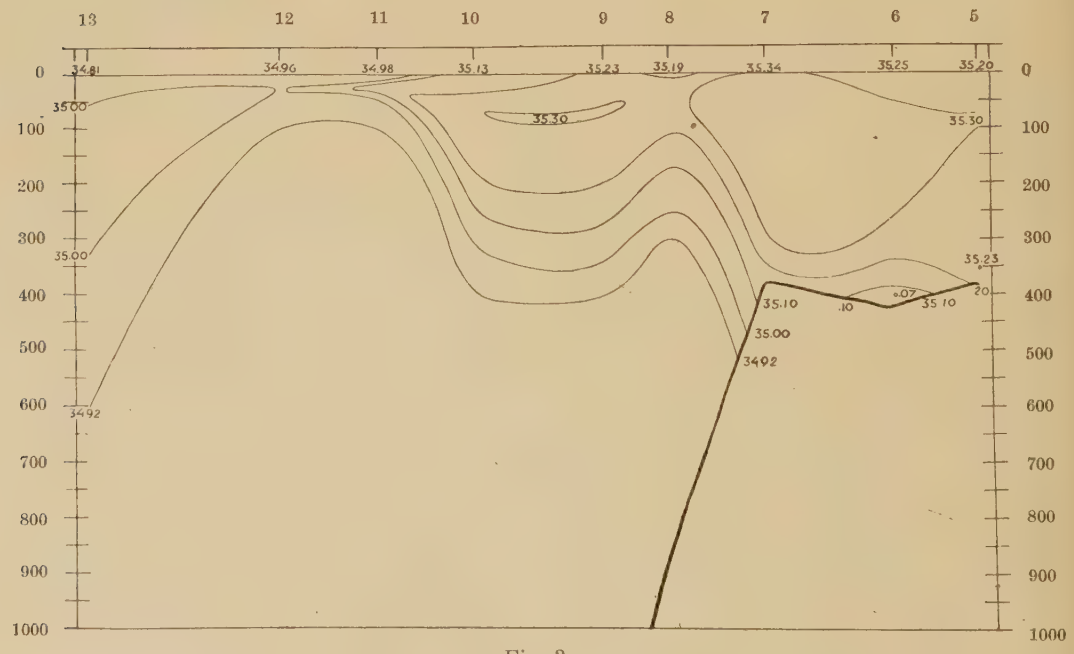
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Fig. 3.

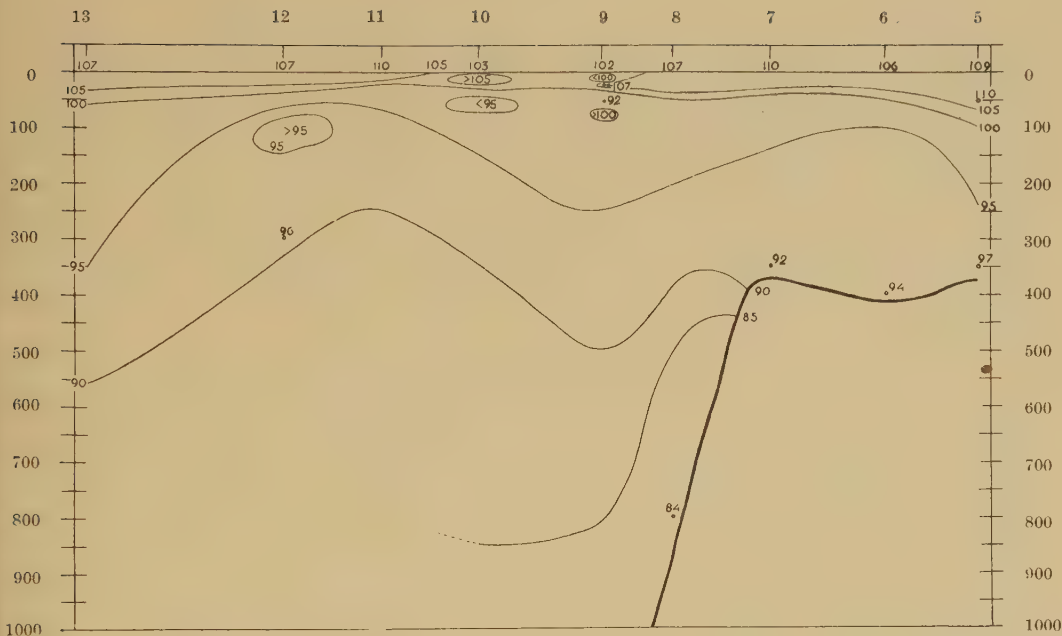
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Fig. 4.

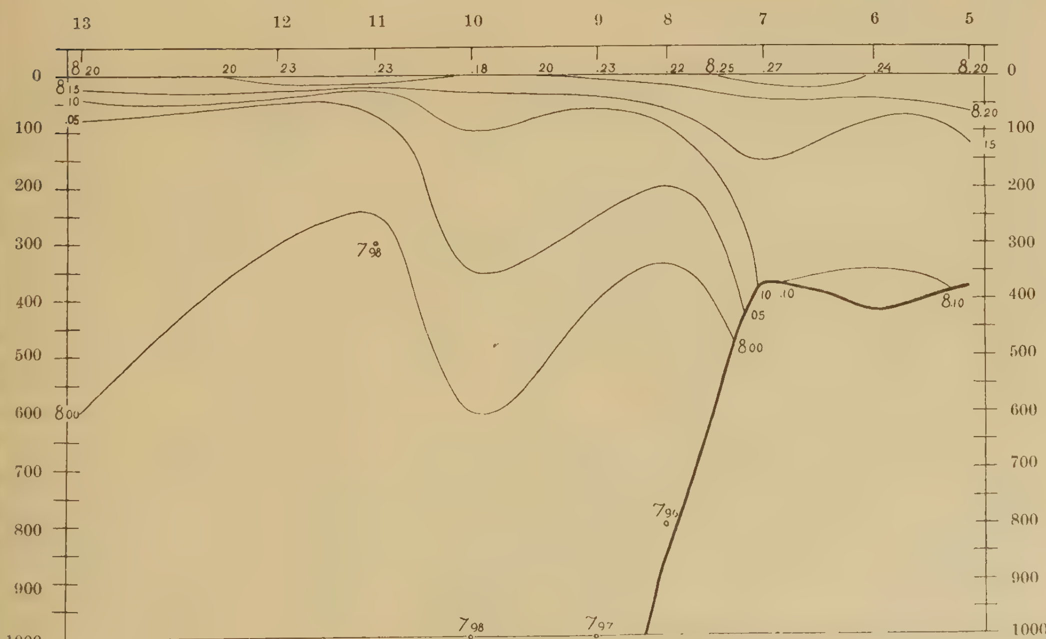
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Fig. 5.

Iceland and is now moving south-east so close to the Faroe Islands that it is not found on Station 12. The temperature of this water is 2—3 degrees, its saturation of oxygen 95—97 per cent. and its $p_H = 8.05$. The principal part of the Atlantic water which enters the Norwegian Sea passes through the Faroe-Shetland channel and is found on the eastern stations of the section. This water has a considerably higher temperature than the water at Station 13 (4—11 degrees). The highest salinity was observed at Station 7 (35.36 ‰), the oxygen saturation is 91—100 per cent., and p_H between 8.02 and 8.27. The indication of a vortex with vertical axis, at Station 8, which is shown by both isotherms and isohalines must be noted.

Under this Atlantic water is a layer, the salinity of which is below 35 ‰ but the temperature of which is above 0°. This arctic water is found at Station 13, partly in the upper 50 metres and partly below 350 metres to the bottom at a depth of 600 metres. At Station 12 it is found at all the depths at which observations were made, from the surface to 300 metres. At Stations 10 and 11 this water is found at a depth between 450 and 650 metres, at Station 8 between 250 and 450 metres. The elevation of the layer at Station 8 is evidently a consequence of the vortex mentioned above. This arctic water comes from the Iceland Arctic Current and flows south-east along the banks off Iceland towards the Faroe-Shetland channel. Under this arctic water the typical bottom-water from the Norwegian Sea with temperatures below zero and a salinity of about 34.92 ‰ is found. The oxygen saturation of the bottom-water lies between 84 and 86 per cent., and its p_H at approximately 7.99.

On the homeward trip a new section was made between the Faroe Islands and the Norwegian channel, but this time about 2 degrees more to the south. This section, Figs. 6, 7, 8 and 9, gives roughly the same distribution of water as the preceding section. On Stations 67, 68, 69, and 72, 73 we find only Atlantic water, which at Station 72 at a depth of 100 meters reaches its highest degree of salinity, namely 35.41 ‰. At Stations 70 and 71 a tongue of arctic water projects under the Atlantic water. At Station 70 this arctic water fills the depth between 40 metres and the bottom, and at Station 71 the depth between 250 and 500 metres. The contents of oxygen of this water lies between 93 and 98 per cent., its p_H at approximately 7.97.

The third section, Figs. 10, 11, 12 and 13, comprises 5 Stations between the south-west coast of Iceland and the southern point of Greenland. In other words, this section lies across one of the communication-gates between the Norwegian Sea and the Atlantic Ocean, but south of the threshold proper, the saddle-depth of which is stated by Helland-Hansen and Nansen[1]) to be about 600 meters. This section shows principally Atlantic water which is found through the entire

[1] Helland-Hansen and Nansen: The Norwegian Sea.

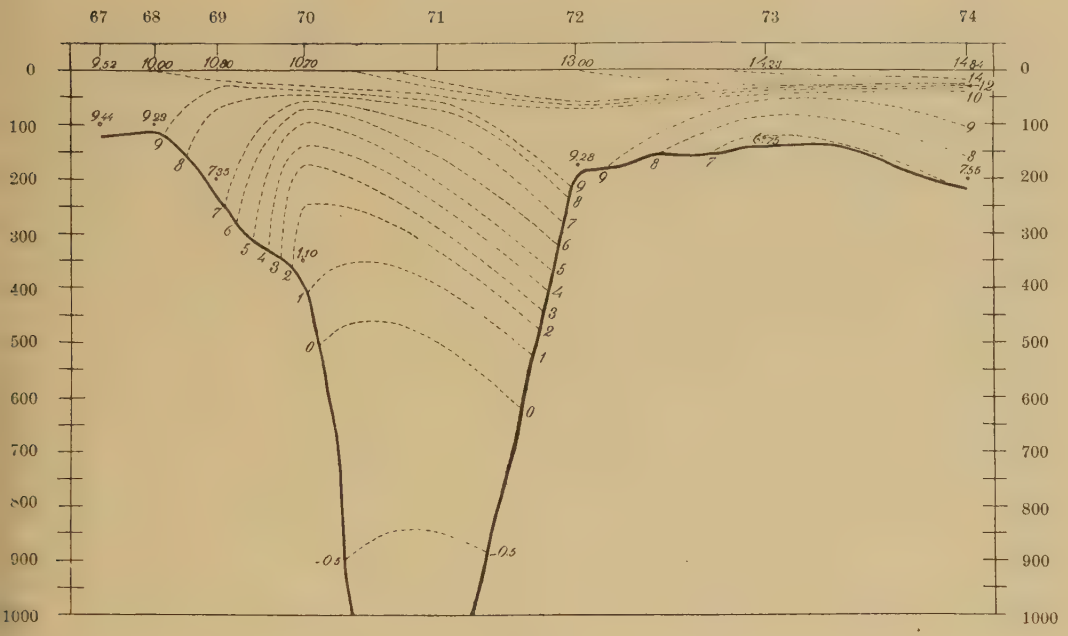
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Fig. 6.

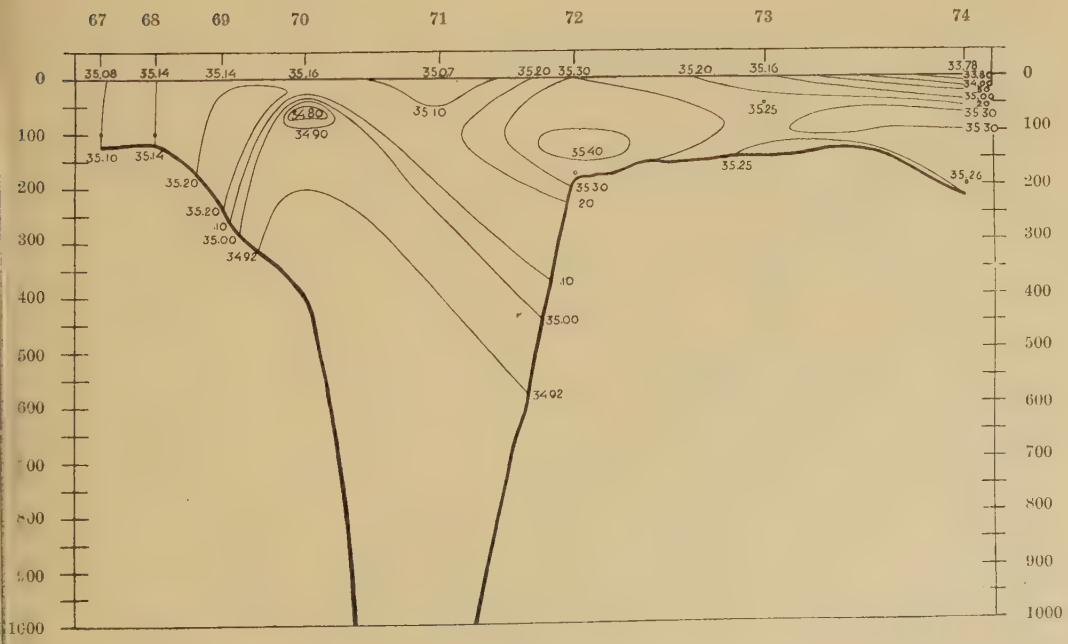
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Fig. 7.

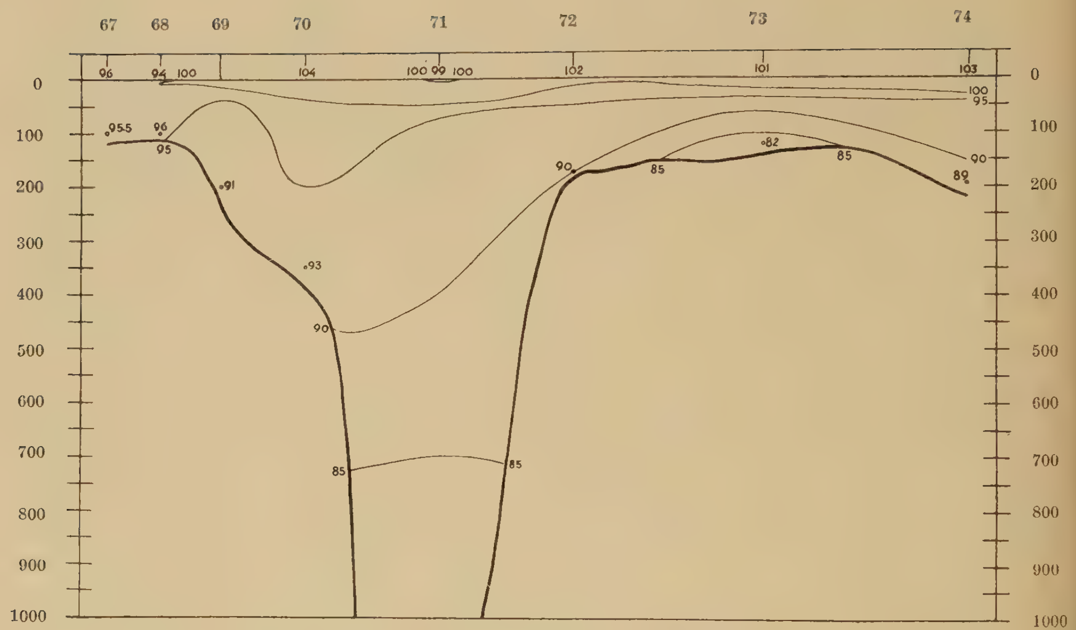
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Fig 8.

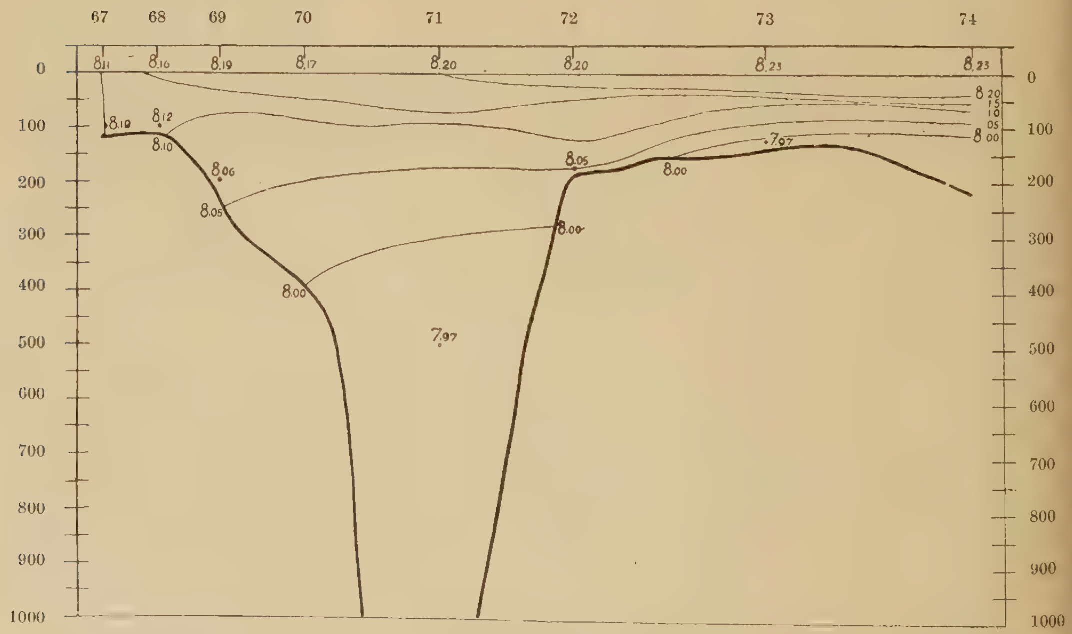
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Fig. 9.

section with the exception of its westernmost stations. At Station 27 Atlantic water is found at all observed depths from the surface to 1000 metres, at Station 28 the amount of it has been reduced to the depths between 50 metres and 350 metres and as we move west its significance is gradually diminishing. Atlantic water is not found on Stations 30 and 31. The temperature of this water is above 5°, its contents of oxygen above 93 per cent. and p_H between 8.20 and 8.00. For the rest this section contains a mixture of Atlantic water and arctic water, the temperature of which is above 3°, and the oxygen contents of which keeps within the same percentage limits as those of the Atlantic water; its p_H goes down to 7.93. The isotherms and the isohalines indicate that the Atlantic water is steadily moving northward in relation to the lower layers of water. This is the Irminger current. The hydrographer of the Ingolfexpedition, Professor MARTIN KNUDSEN, proved that only a part of this current passed through the shallow Denmark Sound into the Norwegian Sea. The greatest part of its water is deflected southwards from Denmark Sound following the edge of the east Greenland coast plateau. On the shelf of that coast flows the Polar current. The ice-floes of that current are exposed to a rapid melting process when the shelf becomes narrower and the ice comes to float over deep water and is attacked from below by the warm and salt water of the Irminger current. This accounts for the scattered state of the icedrift when doubling Cap Farvel.

Thus, in the western part of the section a part of the Irminger current flows in a south-westerly direction, wherefore the question arises as to whether this water can flow around Cape Farvel and constitute the water of Atlantic origin which is found in Davis' Strait. The Norwegian deepsoundings (see Fig. 14) bear out the fact that it is the same water which, having completed its circuit in the Irminger Sea, turns direction and flows northwards into Davis Strait with its salinity reduced from 35.1 or 35.2 ‰ S.W. of Iceland (St. 23, 26, 27) to 34.5 ‰ (St. 63) west of Cap Farvel[1]) — evidently an effect of the icemelting. The loss of heat and salinity of the Atlantic water in the Irminger Sea appears from a comparison between the deepsoundings at Station 27 west of Iceland and Station 29 east of Greenland.

120 miles off Reykjavik in Station 27 the Irminger current carries Atlantic water to a depth of more than 1000 meter into the Greenland Sea. The maximum salinity 35.17 ‰ was found at 100 m. ($t = 7°.13$). Even at a depth of 1000 m. the salinity was 35.03 ‰ ($t = 4°.92$). After its circuit in the Irminger Sea we find the current reduced to a 300 m. thick layer of 35 ‰ water (station 29). South of

[1]) It is of interest to compare the deepsoundings of the Norwegian expedition (1924) with the corresponding soundings made more than 30 years before in the Irminger Sea by the Ingolf expedition (Den Danske Ingolfexpedition: Hydrography by M. KNUDSEN p. 109—112). If we make allowance for a slight discrepancy in the salinity-determinations (those of the Ingolf-expedition (Section XXV) being a trifle higher) there is a remarkable agreement between the results.

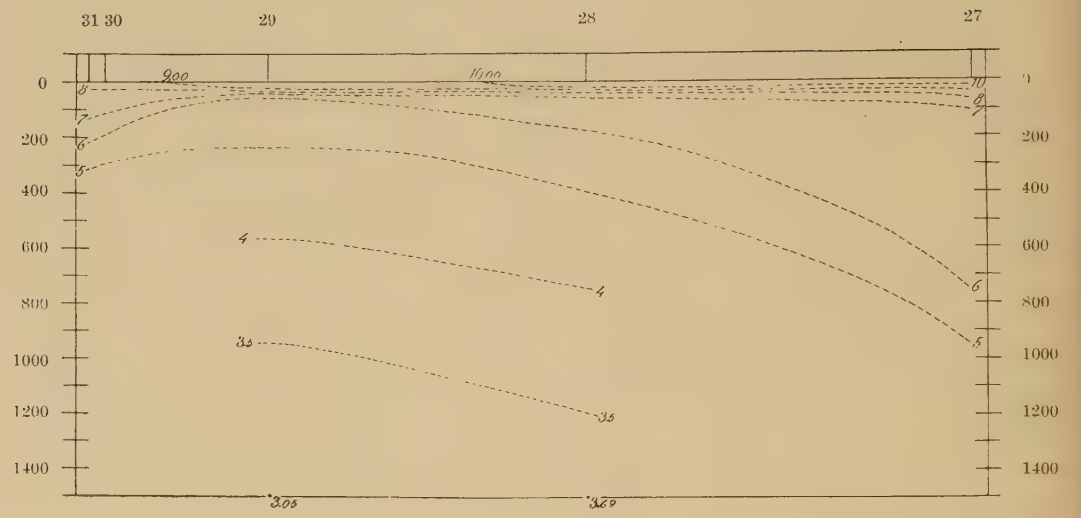
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Fig. 10.

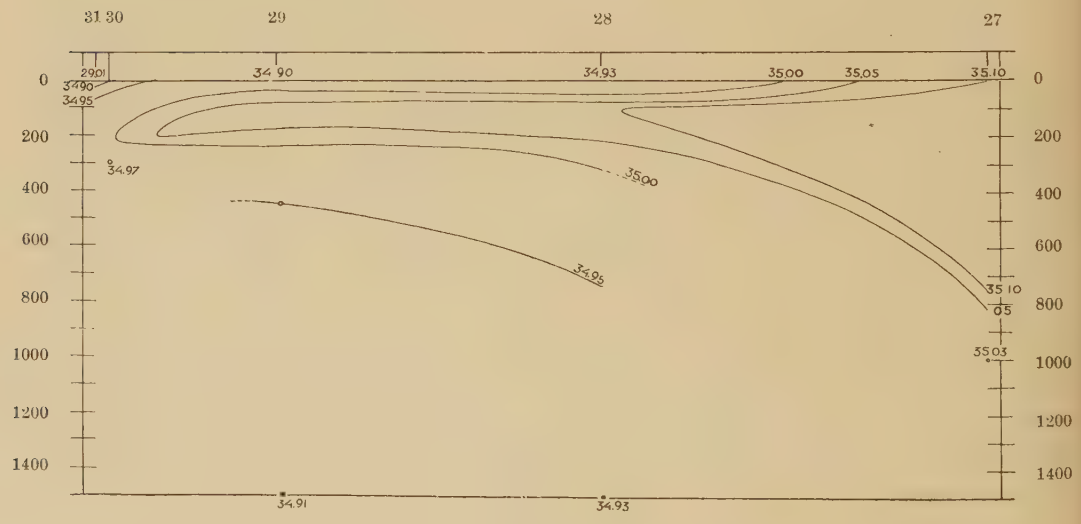
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Fig. 11.

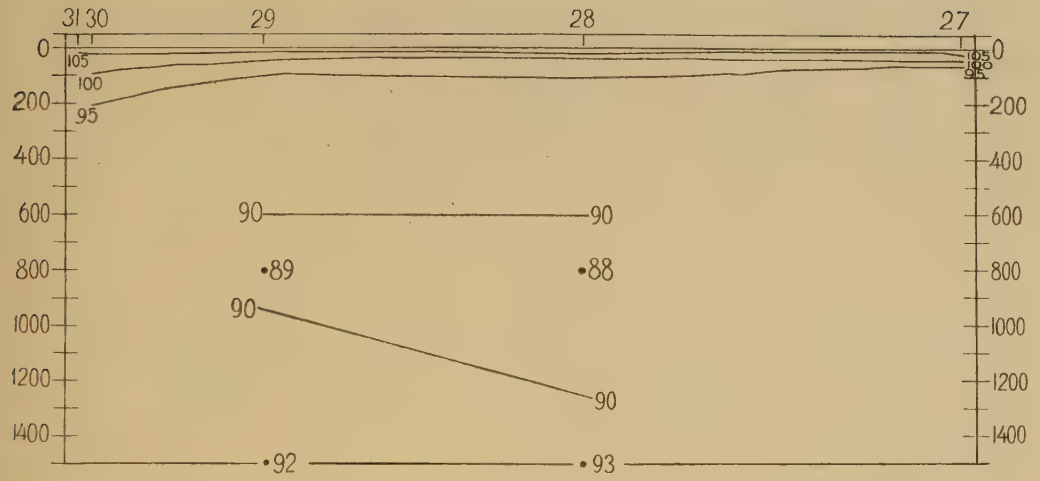
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Fig. 12.

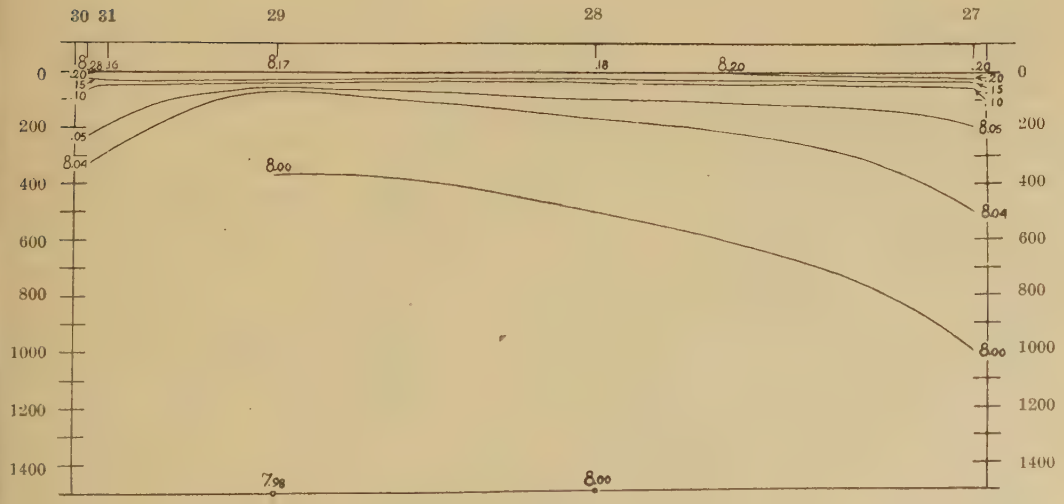
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Fig. 13

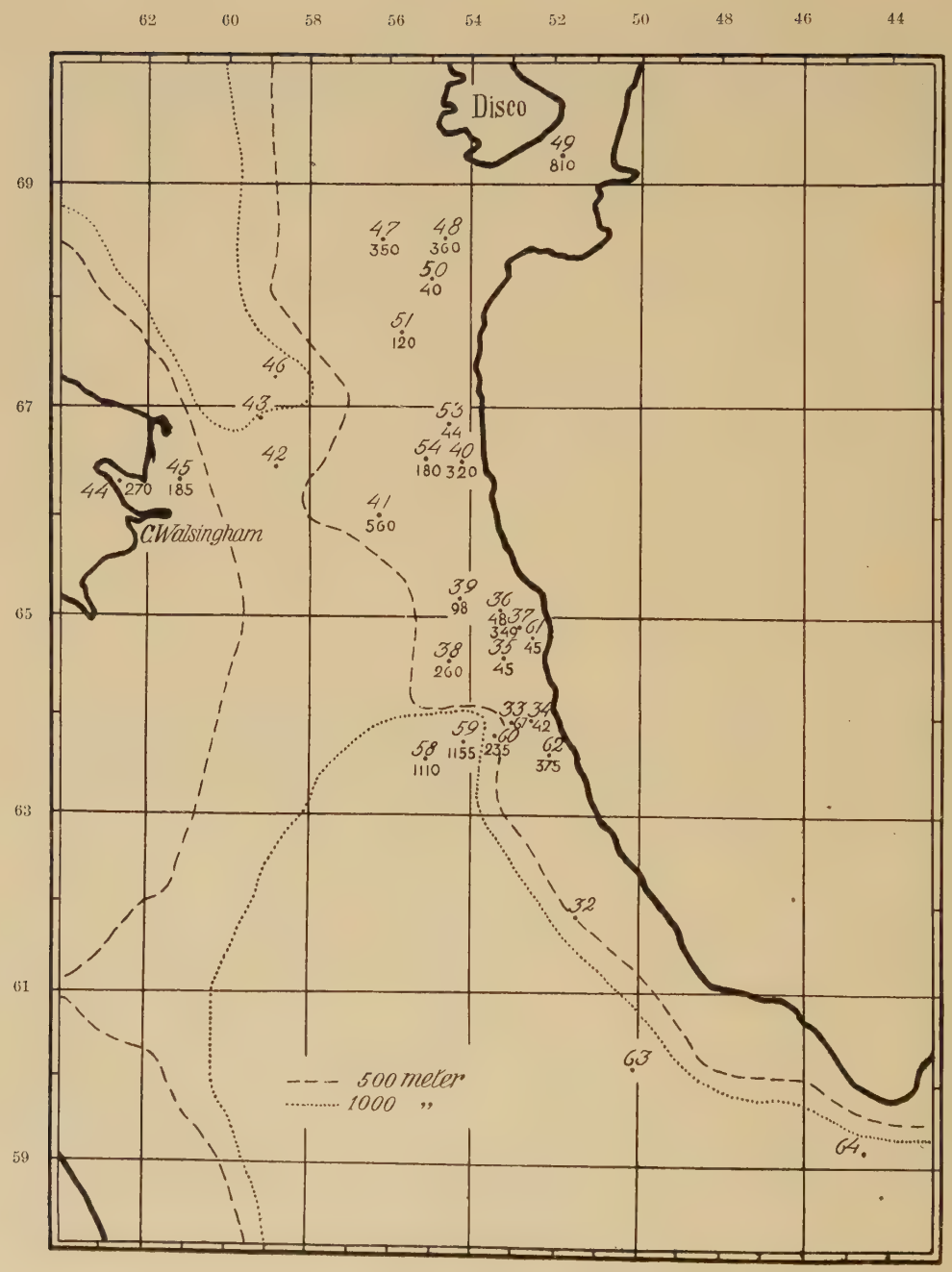
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Fig. 14.

Cap Farvel, after its encounter with the ice (in Stations 30 and 31) its salinity sinks below 35 ‰ (Stations 64 and 65) and west of Cap Farvel in Davis Strait the salinity was always found a little below 35 ‰ and the temperature below 5°, e. g. in stat. 32 where the record of the deepsounding was $t = 4°.99$ and $S = 34.96$ ‰ at 200 m. Except this slight decrease in salinity and temperature caused by the influence of icemelting the quality of the deep waters in Davis Strait is the same as in the Irminger Sea with regard to the content of Oxygen and p_H a token of their common origin.

Station 29	Station 32
Irminger Sea. Depth 300 m.	Davis Strait. Depth 300 m.
61° N. Lat. 37°55′ W. Long.	61°50′ N. Lat. 51°26′ W. Long.
$t = 4°.78$; $S = 34.97$ ‰	$t = 4°.64$; $S = 34.96$ ‰;
$O_2 = 6.65$ cc/L; $p_H = 8.04$	$O_2 = 6.70$ cc/L; $p_H = 7.97$

This inflow of Atlantic water in Davis Strait via the Irminger Sea reaches as far as to the submarine ridge between Davis Strait and Baffins Bay (see the longitudinal Section) where the Atlantic water crops out against the submarine treshold of the strait. On the other side of that ridge we have arctic water with highly reduced Oxygen per-cent and P_H. Baffins Bay from Davis Strait to Smiths Sound has from a hydrographical point of view the character of an arctic fjord.

We can follow these collateral currents of arctic and Atlantic water at the various stations in Davis' Strait.

Station 63 is situated at a distance of about 60 nautical miles from the coast of Greenland. At this station the only observation at which Atlantic water was found west of Greenland, was made at a depth of 100 metres. From the available observation-material it cannot be ascertained whether this Atlantic water only originates in a branch of the Irminger current, or whether it also comes from the northerly branch of the Atlantic current, as recently asserted by Dr. V. I. Pettersson[1]).

Stations 62, 34, 33, 60, 59 and 58 are lying across Fylla's Bank off Godthaab, in such a manner that they together give a section from the coast across the bank and through the body of water flowing around the bank. This section is shown in Fig. 15. In this section the general tendency of isotherms and isohalines to slope towards the coast, showing that the upper layers are moving northward in relation to the lower ones, is very marked. The most remarkable feature of this section is the colder volumes of water found over the bank proper. The continued warming up of the water of the East Greenland current which can be ascertained from the passage of the water through Denmark' Strait, seems to have

[1]) V. I. Pettersson: Etude de la statistique Hydrographique du Bulletin Atlantique du Conseil International pour l'Exploration de la Mer. Svenska Hydr.-Biol. Komm. Skrifter 1926.

been interrupted here. A study of the Danish Ice-charts[1]), month by month will explain the matter. These ice-charts indicate that the ice over the banks at the south-western coast of Greenland, Fylla's Bank, and the Hellefiske Bank, remains even after the surrounding ice has disappeared. It is this continuation of the colder situation which is also indicated by the section.

A section through Stations 37, 35 and 38 show similar conditions on the Hellefiske Bank and need not be specially mentioned.

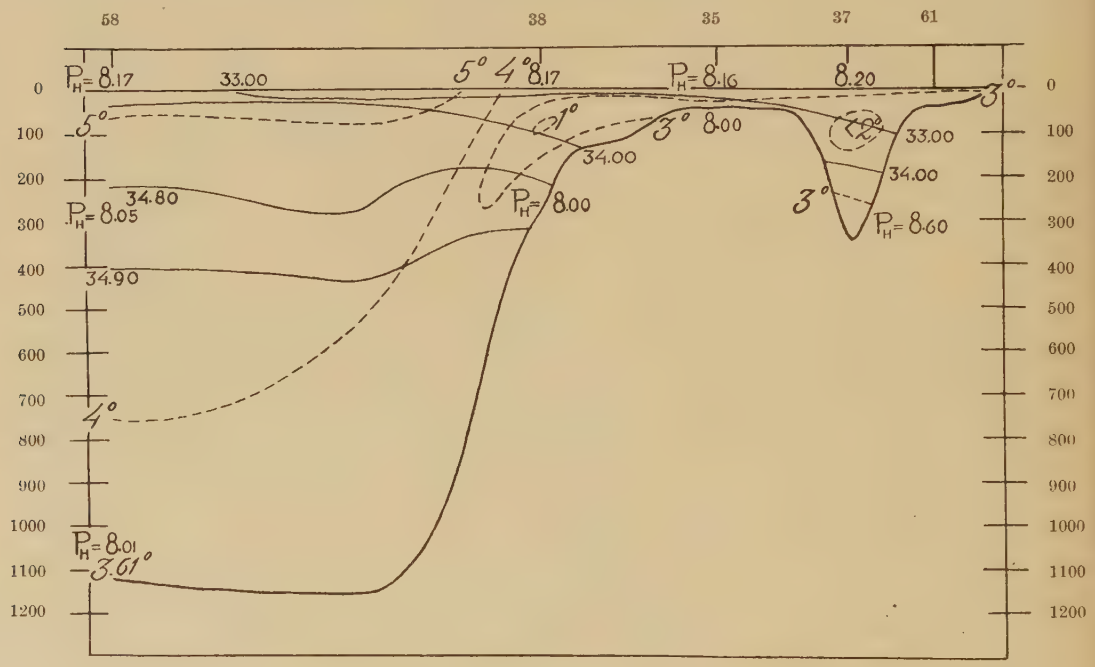


Fig. 15.

The longitudinal section through Stations 58, 41, 42, 43 and 46 (Figs. 16, 17, 18 and 19) should be studied simultaneously with the section through Stations 40, 54, 41, 42, 43 and 45 (Figs. 20, 21, 22 and 23). The distance between Stations 41 and 43 is covered in both sections, although its true position is a little outside of both sections.

We first note that both isotherms and isohalines across and inside the bank off the western coast of Greenland are sloping towards the coast, which indicates that the surface water also here is moving northwards in relation to the lower layers. Outside of the bank we find water of comparatively high salinity and temperature, with contents of oxygen exceeding 90 per cent. and p_H above 7.95. This water is evidently of southern origin and flowing northwards. At Station 42

[1]) Nautical-Meterological Annual, Copenhagen.

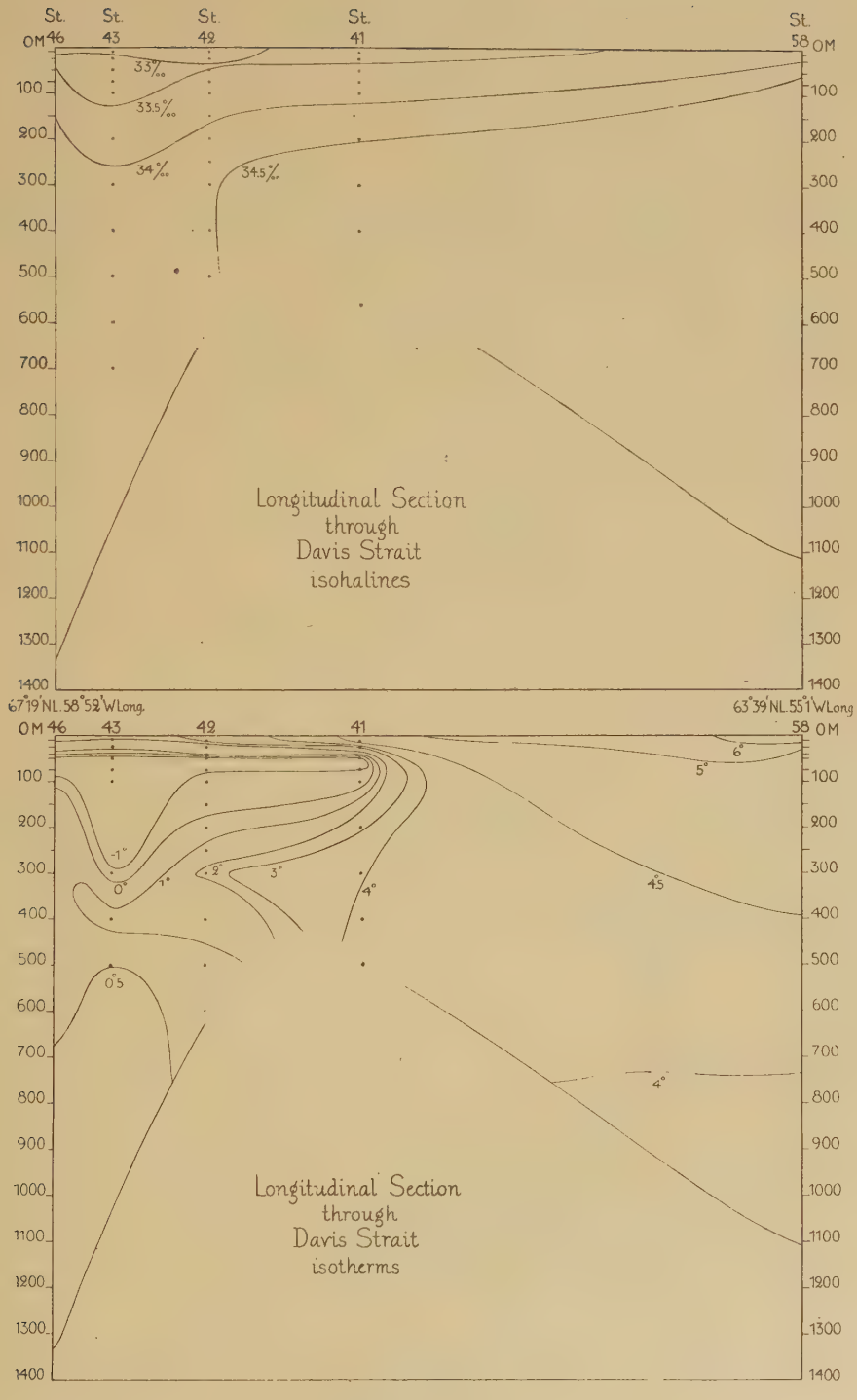
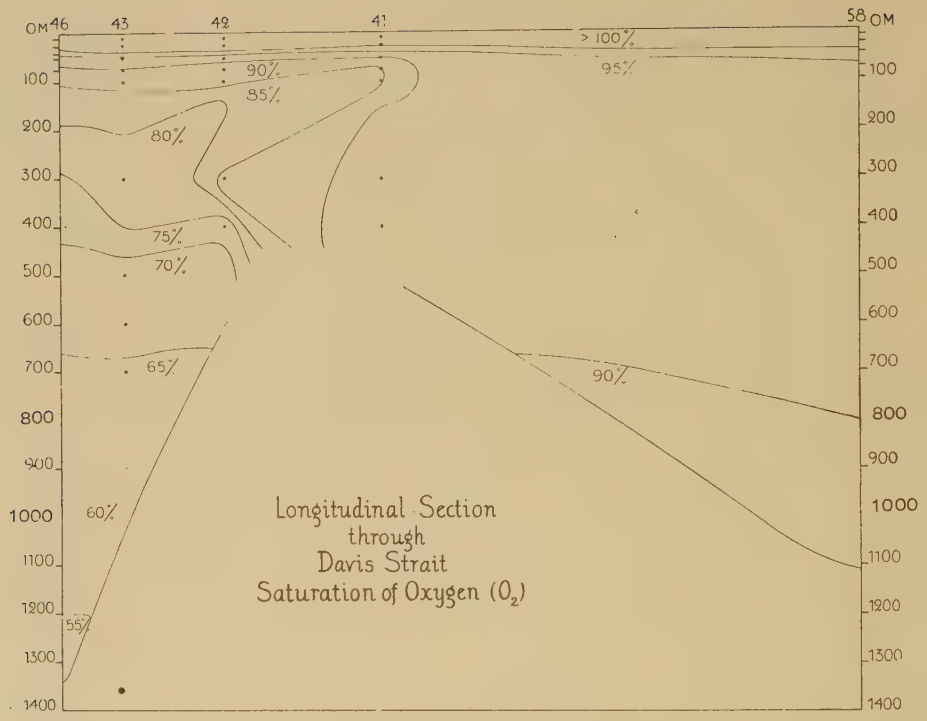

St. 46
St. 43
St. 42
St. 41
St. 58
OM
33‰
33.5‰
34‰
34.5‰
Longitudinal Section
through
Davis Strait
isohalines
67°19'NL. 58°52'W Long.
63°39'NL. 55°1'W Long.
-1°
0°
1°
2°
3°
4°
4.5
5°
6°
0.5
Longitudinal Section
through
Davis Strait
isotherms

Fig. 16 and 17.


OM 46 43 42 41 58 OM
> 100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
90%
Longitudinal Section
through
Davis Strait
Saturation of Oxygen (O_2)

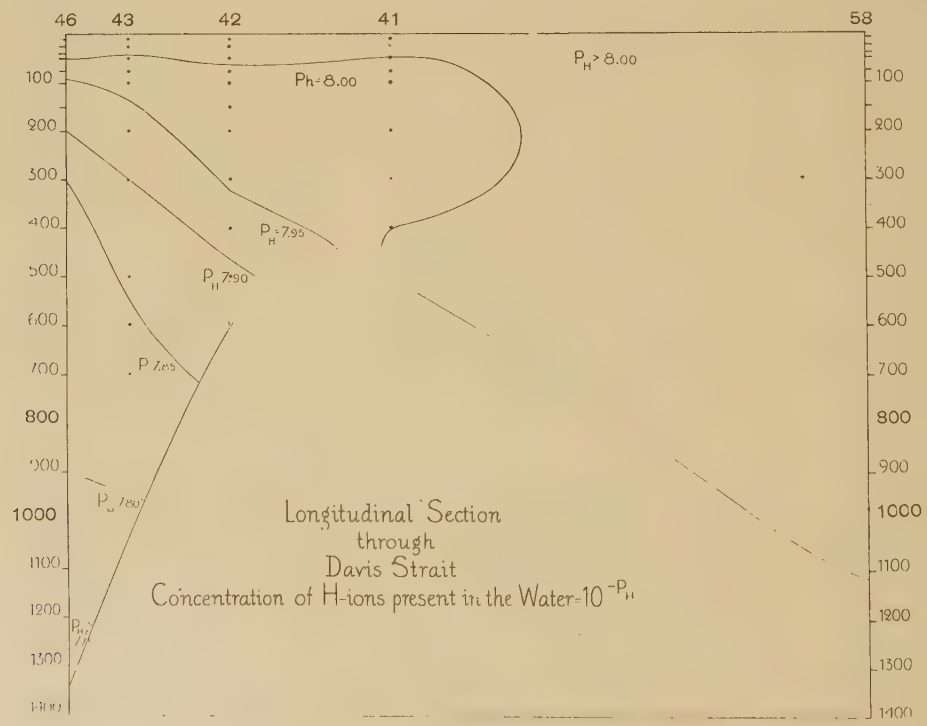

46 43 42 41 58
P_H > 8.00
Ph=8.00
P_H=7.95
P_H 7.90
P 7.85
Longitudinal Section
through
Davis Strait
Concentration of H-ions present in the Water=10^{-P_H}

Fig. 18 and 19.

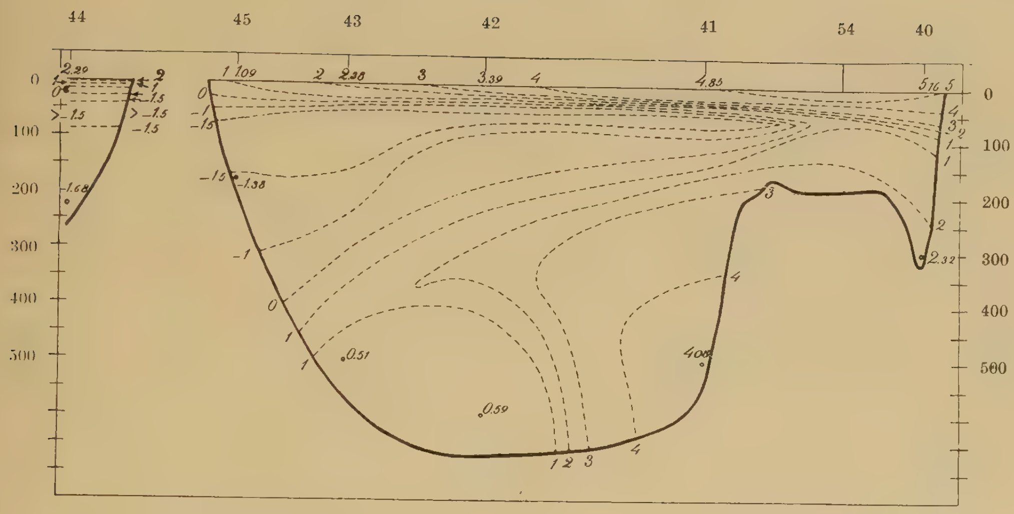


Fig. 20.

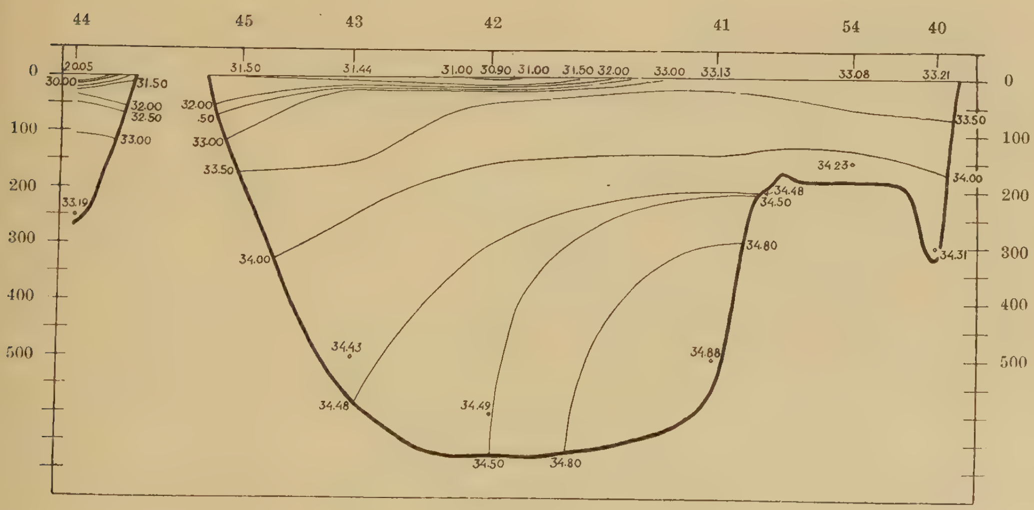


Fig. 21.

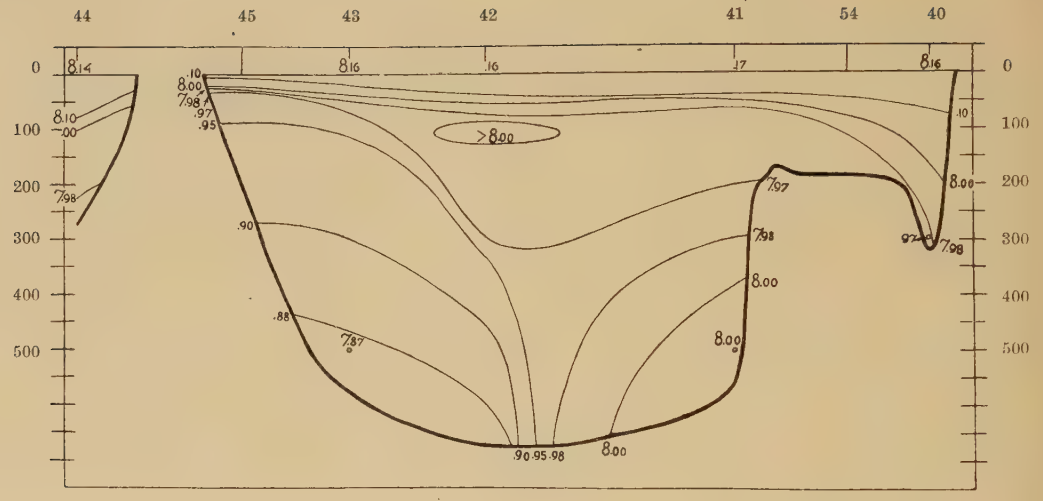

44
45
43
42
41
54
40
0
100
200
300
400
500
>8.00
.90.95.98
8.00

Fig. 22.

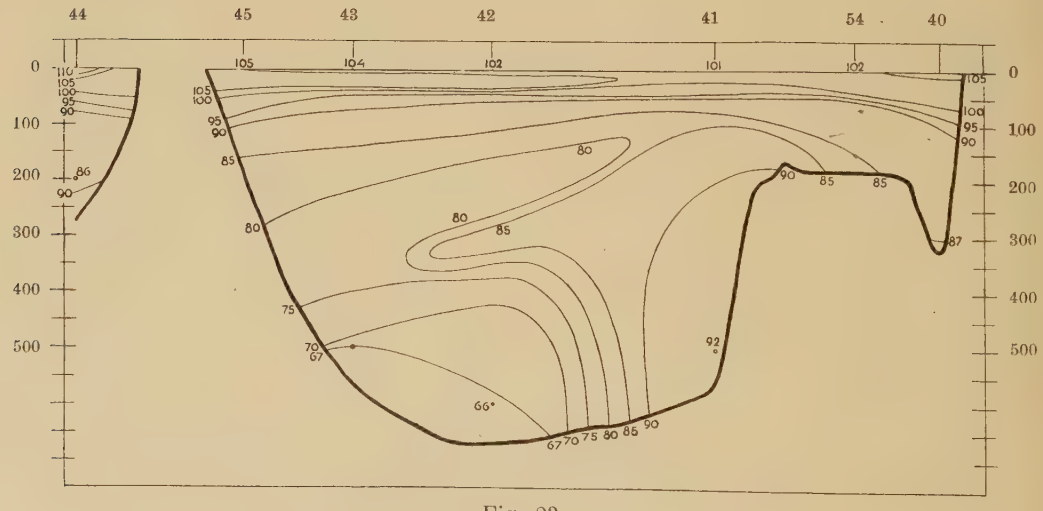

44
45
43
42
41
54
40
0
100
200
300
400
500
105
104
102
101
102
80
85
90
92
66°
67 70 75 80 85 90

Fig. 23.

we still find this water at a depth of 200 metres, with temperature 2.1°, salinity 34.49 ‰, oxygen-contents 88 per cent., and $p_H = 7.97$. But when the depth is increased the character of the water changes. At a depth of 600 metres we find a temperature of 0.59°, salinity 34.49 ‰, oxygen-contents 66 per cent. and $p_H = 7.88$. This change in the nature of the water is evidently not only caused by the increased depth — at Station 58 at a depth of 600 metres the temperature is 4.24°, salinity 34.90 ‰, oxygen-contents 92 per cent., and $p_H = 8.04$, — but there is another reason. The water cannot have come from the south, but from the north, or it must at least have been mixed to a great extent with water from the north. This view will be strengthened if we consider the longitudinal section. We see, that north of the threshold in Davis' Strait we find quite other conditions than south of the treshold. At Station 43, at a depth of 500 metres the temperature is 0.51°, salinity 34.43 ‰, oxygen contents 67 per cent., and $p_H = 7.87$. It is evidently this water which has been pressed up to threshold and which appears at a depth of 600 meters at Station 42. The longitudinal section clearly proves the following view of the movement of the water across the threshold. Between approximately 500 metres and 200 metres southerly, warmer water is moving northwards. Above 200 metres colder water is flowing southwards. The temperature of this water increases, however, towards the surface on account of heating from above. Below 500 metres there is perhaps a current of cooled, cold water flowing southwards. This is exactly the typical current caused by melting ice in the sea, as shown by Professor O. Pettersson[1]).

In other words, we have found currents across the threshold in two opposite directions, between these currents there must be a dividing-line connecting the water-particles the velocity of which is zero, a zero-line. The course of this dividing-line might be further ascertained by comparing the hydrographic observations in accordance with the methods prepared by Helland-Hansen and J. W. Sandström[2]) according to the theory of Professor Bjerknes. For the purpose of this comparison the quantities found in Table II have been compiled, and from these quantities the CGS solenoids and anomalies of the specific volume shown in Fig. 24 have been calculated in accordance with a well-known formula In Fig. 25 the analogous values are given for the Longitudinal section through the Davis Strait. On account of the nature of these methods they do not give the absolute figures for the velocity of the currents but only the differences in velocity. To complete the illustration of the movements of the water we are therefore obliged to resort to suppositions. The supposition which is nearest at hand, namely, that the layer of water closest to the bottom is stationary cannot be used

[1]) O. Pettersson: On the influence of Ice-melting. Svenska Hydr.-Biol. Komm. Skrifter III.

[2]) J. W. Sandström: The Hydrodynamics of Canadian Atlantic Waters, Canadian Fisheries Expedition 1914—1915.

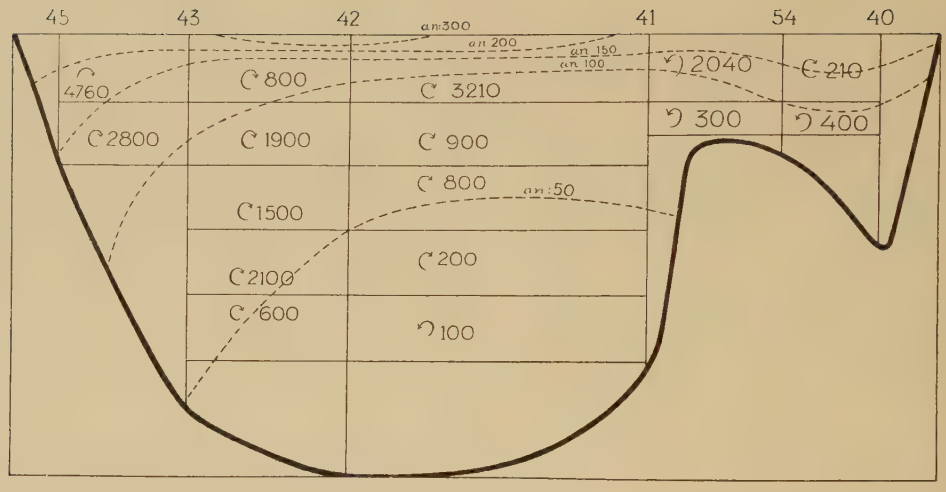

45
43
42
41
54
40
an 300
an 200
an 150
an 100
4760
800
3210
2040
210
2800
1900
900
300
400
800
an 50
1500
200
2100
600
100

Fig. 24.

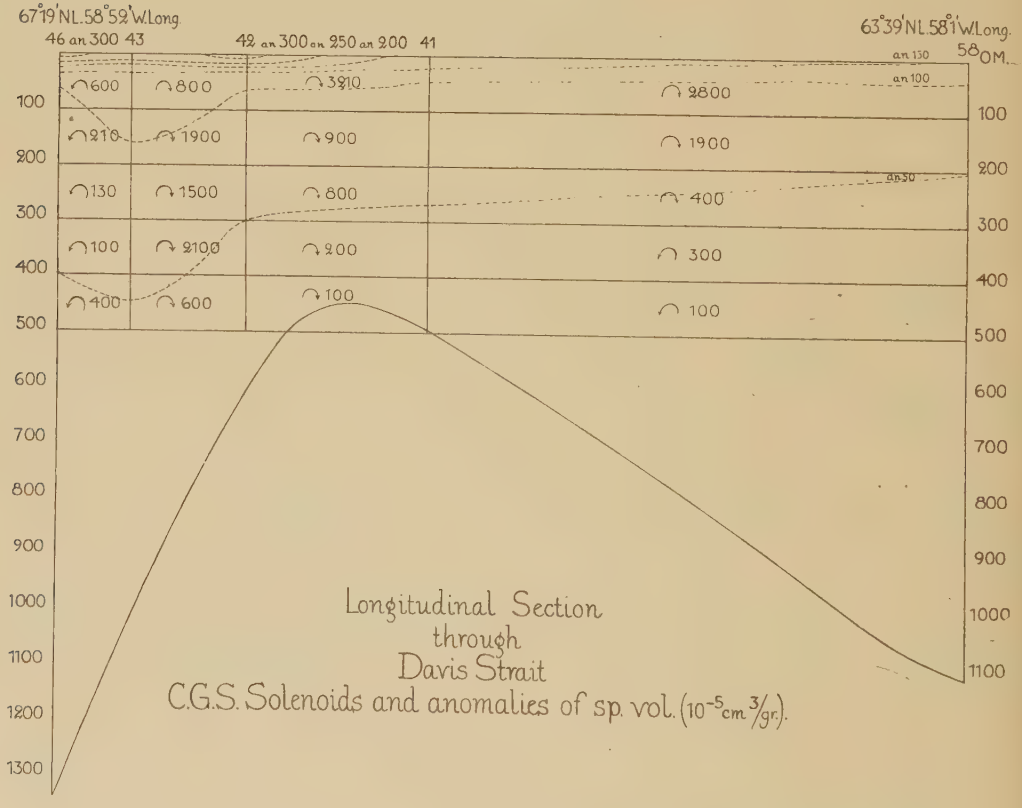

67°19'NL. 58°52'W.Long.
46 an 300 43
42 an 300 an 250 an 200 41
63°39'NL. 58°1'W.Long.
58 OM.
an 150
an 100
an 50
600
800
3210
2800
210
1900
900
1900
130
1500
800
400
100
2100
200
300
400
600
100
100
Longitudinal Section
through
Davis Strait
C.G.S. Solenoids and anomalies of sp. vol. (10^{-5} cm^3/gr.)

Fig. 25.

as neither theories nor observations permit a calculation of velocity-differences in relation to the layer of water lying immediately over the bottom. A supposition of a constant velocity of the surface water might also be imagined, as it might be possible to ascertain this surface-velocity by continuity considerations of Baffins' Bay as an enclosed bay (not considering the movement of water which might take place through its northern mouth). The supposition of a constant surface-velocity is, however, at variance with the picture of the movements of the water given by the hydrographic observations. We have therefore selected the supposition that the movement of the surface-water takes place in such a manner that the

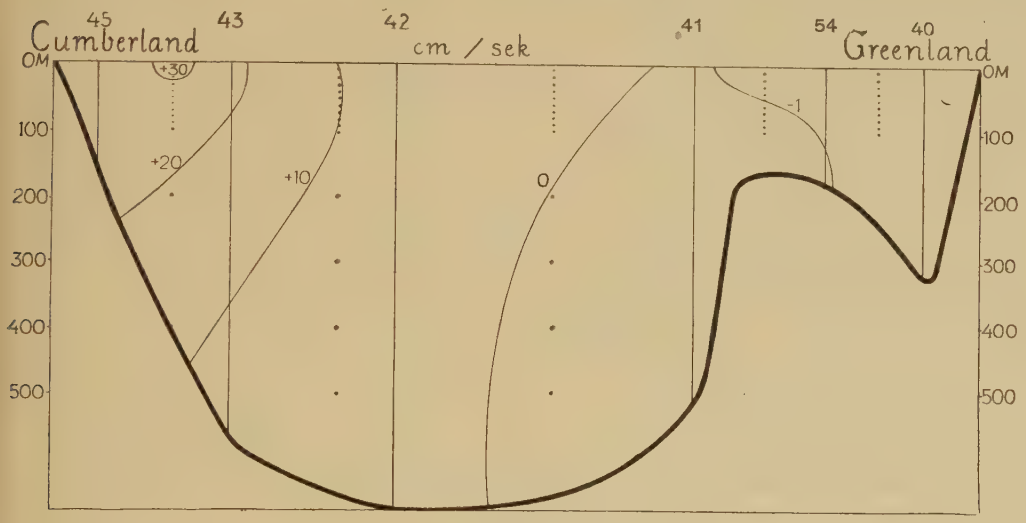


Fig. 26.

particles of water which at a certain time are on a line across Davis' Strait after a short time still are in a straight line, intersecting the first line at a certain point and at a certain angle. For hydrographic reasons a point immediately west of Station 41 has been selected as point of intersection (surface-velocity = zero). In order to ascertain the angle between the two lines it has been necessary to suppose a certain velocity at some other place in the section. In doing this we have considered the information regarding the drifting of the icebergs given by Captain Speerschneider in the Danish ice-reports, and as a result we have supposed that the movement of the water off the coast of Labrador is southward at the rate of 30 centimetres per second. Of course, these suppositions regarding the movements of the water are doubtful, but they might roughly afford a true picture of these movements. Upon these suppositions the velocity of the water at various points of the section has been calculated. The result is shown in Fig. 26 which shows the course of the lines connecting the points having the same velocity.

Table I. Temperature, salinity, σ_t, contents of oxygen, degree of oxygen saturation and hydrogen ionconcentration.

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
St. 1. VII 9 64°12′ N 7°17′ E 320 m						
1	10,70	33,96	26,04	6,50	104	8,21
10	66	96	05	50	104	20
20	9,96	34,04	23	55	104	20
30	09	6,29	56	63	103	20
40	6,64	8,51	27,10	47	95	17
50	66	72	26	29	92	17
75	8,16	35,14	38	22	95	16
100	7,80	15	43	27	95	15
200	34	15	50	21	93	15
300	6,82	16	59	48	95	15
St. 2. VII 10 63°12′ N 6°36′ E 150 m						
1	9,75	32,83	25,32	6,60	104	8,22
10	75	84	33	57	103	19
25	20	33,40	86	64	103	19
40	5,80	77	26,62	53	94	08
50	54	34,11	93	35	91	08
75	66	16	94	52	93	06
100	6,29	83	27,40	30	92	06
140	19	92	48	13	89	06
St. 3. VII 10 63°9′ N 5°30′ E 180 m						
1	8,55	33,93	26,37	6,81	104	8,17
10	75	34,69	94	67	103	15
25	89	97	27,14	49	100	13
50	16	35,17	40	33	96	12
75	7,81	19	47	27	95	10
100	39	19	53	26	94	08
150	6,77	18	62	48	95	08
St. 4. VII 10 62°38′ N 3°40′ E 678 m						
1	11,37	34,74	26,54	6,62	108	8,20
10	10,30	35,25	27,11	86	109	18
20	10	25	16	97	110	17
30	9,93	25	16	53	103	22
40	45	27	23	43	100	16
50	27	26	30	31	98	10
75	8,80	30	40	15	95	14
100	70	36	47	15	94	12
200	7,28	25	59	31	94	13
300	6,70	21	65	44	94	08
400	5,86	17	73	48	94	05
500	32	15	78	58	94	09
600	3,31	00	89	68	91	09
St. 5. VII 10 62°37′ N 3°37′ E 375 m						
1	10,35	35,20	27,08	6,83	108	8,20
10	22	21	10	69	106	23
25	50	26	09	87	110	20
50	10,50	35,26	27,09	6,90	110	8,21
75	9,42	30	30	60	103	19
100	8,91	30	39	49	100	16
200	7,87	27	53	36	96	12
300	7,39	23	56	45	96	14
St. 6. VII 11 62°21′ N 2°25′ E 417 m						
1	10,96	35,25	26,99	6,58	106	8,24
10	98	25	99	66	107	22
25	31	27	27,12	72	107	23
50	9,35	32	33	46	101	17
75	8,90	33	42	24	97	15
100	88	34	42	18	96	15
200	18	33	53	21	95	12
300	7,02	26	64	43	95	11
400	4,21	07	84	73	94	08
St. 7. VII 11 62°6′ N 1°0′ E 375 m						
1	11,16	35,34	27,03	6,83	110	8,27
10	05	34	05	76	109	26
25	10,91	34	08	66	107	23
50	9,87	34	27	06	96	18
75	36	36	37	30	98	16
100	8,98	35	42	45	99	16
200	60	35	47	37	98	13
300	7,82	26	53	34	96	12
350	6,81	20	63	45	95	12
St. 8. VII 11 62°20′ N 0° Long. 860 m						
1	11,03	35,19	26,93	6,60	107	8,22
10	...	20	...	29	...	21
25	9,81	21	27,17	66	106	18
50	8,01	23	47	55	100	16
75	6,95	22	63	48	96	12
100	57	21	67	67	98	08
200	4,26	05	81	83	95	05
300	1,90	34,92	93	7,15	94	00
400	0,17	92	28,05	6,99	88	7,99
500	—0,56	93	09	92	86	97
600	— 71	93	10	90	85	98
700	— 81	93	10	74	83	97
800	— 90	92	10	88	84	96
St. 9. VII 11 62°32′ N 0°45′ W 1500 m n. b.						
1	10,29	35,23	27,10	6,43	102	8,23
10	28	23	10	5,86	93	19
25	9,18	24	29	6,88	107	18
50	8,43	29	45	12	93	12
75	7,94	30	53	82	103	09
100	28	24	59	58	98	09

m	$t°$	S ‰	σ_t	$O \frac{ccm}{lit.}$	M %	p_H
200	6,18	35,20	27,71	6,65	96	8,07
300	4,65	06	78	76	95	02
400	1,95	34,92	93	7,00	92	00
500	0,89	91	28,01	05	90	00
600	—0,03	93	07	6,88	86	7,98
700	— 33	92	07	96	86	97
800	— 53	94	10	86	85	97
900	— 69	92	10	77	84	96
1000	— 87	91	10	90	84	97

St. 10. VII 12 62°47′ N 2°12′ W 1900 m n. b.

1	9,86	35,13	27,11	6,50	103	8,18
10	70	16	15	80	107	18
25	8,93	17	30	85	106	16
50	7,70	25	52	24	94	13
75	43	25	56	35	95	12
100	16	25	61	67	99	10
200	6,27	18	69	33	92	08
300	4,04	03	82	55	91	06
400	1,11	34,93	28,00	80	88	04
500	0,69	92	02	99	88	02
600	0,07	92	06	85	86	7,99
700	—0,21	92	07	90	86	8,01
800	— 40	92	09	96	86	7,99
900	— 49	93	09	82	85	98
1000	— 66	92	10	93	85	98

St. 11. VII 12 63°3′ N 3°25′ W n. b.

1	9,04	34,98	27,11	7,08	110	8,23
10	8,91	99	14	15	111	22
25	5,77	35,12	70	6,85	99	10
50	3,76	34,99	83	7,13	98	08
75	39	96	84	17	98	04
100	2,13	92	91	15	95	03
200	1,16	92	99	52	96	8,00
300	0,51	90	28,02	27	92	7,98

St. 12. VII 12 63°18′ N 4°35′ W n. b.

1	8,74	34,96	27,14	6,98	107	8,23
10	70	94	14	7,00	108	20
25	6,91	95	43	33	106	18
50	3,66	97	83	15	98	05
75	2,48	96	91	00	93	...
100	1,93	92	93	34	96	...
200	45	92	97	19	93	...
300	0,83	91	28,01	10	90	8,00

St. 13. VII 13 63°50′ N 7°2′ W 1500 m

1	7,44	34,81	27,23	7,15	107	8,16
10	40	87	28	14	107	16
25	6,22	85	42	37	107	15
50	3,48	99	85	38	100	08
75	18	35,03	91	21	98	05
100	2,96	05	94	22	97	05
200	68	05	97	33	98	06
300	08	01	28,00	27	96	05
400	1,49	34,99	03	28	95	03
500	0,56	34,97	28,08	7,37	93	8,03
600	10	93	08	03	88	00

St. 14. VII 14 62°35′ N 5°45′ W 190 m

1	9,49	35,17	27,19	6,33	99	8,23
10	29	21	25	38	99	20
25	8,95	24	33	20	96	19
50	65	25	38	18	95	17
75	...	24	...	16	...	17
100	7,74	25	52	15	93	14
150	67	23	52	17	93	08
175	85	25	52	26	94	08

St. 16. VII 16 63°5′ N 7°30′ W 805 m

1	10,17	35,25	27,13	...	...	8,19
10	9,83	25	18	...	...	16
25	74	25	20	...	...	15
50	17	25	30	...	...	13
75	7,96	26	50	...	...	08
100	60	25	54	...	...	07

St. 21. VII 18 63°0′ N 8°20′ W 540 m

1	10,14	35,25	27,14	...	...	8,19
10	11	25	14	...	...	18
25	01	25	16	...	...	17
50	8,55	25	40	...	...	16
75	33	26	45	...	...	15
100	08	26	49	...	...	15
200	7,54	25	57	...	...	14
300	6,77	21	65	...	...	11
400	2,77	34,92	86	...	...	10
500	0,80	89	99	...	...	07

St. 22. VII 19 62°13′ N 12°6′ W 980 m

1	11,03	35,19	26,94	6,57	106	8,25
10	00	22	97	62	107	25
25	9,93	22	27,16	67	106	19
50	...	24	...	40	...	17
75	8,45	25	41	40	98	16
100	17	25	45	34	97	12
200	7,83	25	50	30	96	11
300	66	24	53	35	96	10
400	66	24	53	26	95	10
500	59	23	53	20	94	09
600	47	23	55	22	94	10
700	30	23	57	20	92	10
800	6,94	20	61	17	92	07
900	5,04	12	78	28	89	05

St. 23. VII 20 62°47′ N 19°9′ W 1460 m

1	11,59	35,19	26,83	6,47	106	8,23
10	49	19	85	40	105	23
25	8,74	21	27,34	25	96	12
50	61	23	37	20	95	12
75	38	23	41	19	95	12
100	13	25	46	16	94	13

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
200	7,73	35,25	27,52	6,18	94	8,07
300	63	23	53	16	94	07
400	43	21	54	14	92	06
500	24	22	58	20	93	05
600	01	20	60	22	92	05
700	6,77	20	63	27	93	04
800	43	20	68	30	93	03
900	5,73	14	72	37	92	03

St. 24. VII 21 63°19′ N 20°1′ W 200 m

1	10,90	35,05	26,85	7,15	115	8,23
10	81	05	86	20	116	20
25	9,90	12	27,08	6,83	108	18
50	55	14	16	57	103	17
75	8,10	17	42	50	99	13
100	7,65	21	51	31	95	07
150	45	21	54	20	93	05
175	35	21	56	18	93	06

St. 26. VII 21 63°30′ N 21°34′ W 130 m

1	10,75	35,05	26,87	7,18	115	8,26
10	62	07	91	20	116	25
25	9,55	14	27,15	6,71	105	23
50	8,78	17	31	38	99	16
75	7,48	20	53	28	96	08
100	14	19	57	30	94	06

St. 27. VII 29 63°29′ N 26°45′ W > 1220 n. b.

1	10,37	35,10	26,99	6,78	108	8,20
10	33	10	27,00	78	108	21
25	9,46	12	15	56	103	19
50	8,25	12	34	36	97	11
75	7,39	12	47	31	94	08
100	13	17	56	...	...	06
200	6,85	14	57	...	...	05
300	77	14	58	...	...	05
400	71	14	59	...	...	05
500	59	15	62	...	...	04
600	35	15	65	...	...	04
700	18	14	65	...	...	03
800	5,67	06	65	...	...	01
900	25	03	69	...	...	00
1000	4,92	03	75	...	...	00

St. 28. VII 30 62°20′ N 33°1′ W n. b.

1	10,80	34,93	26,70	6,78	109	8,18
10	75	94	79	82	109	19
25	9,75	94	97	87	108	15
50	7,21	35,00	27,41	45	96	07
75	6,93	01	46	25	93	07
100	93	08	51	43	95	05
200	5,88	06	63	55	95	04
300	58	01	64	56	95	03
400	01	34,98	69	37	91	01

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
500	4,56	34,97	27,73	6,49	91	8,00
600	30	98	77	42	90	7,99
700	12	97	78	32	88	8,00
800	3,93	95	78	37	88	7,99
900	67	93	78	47	89	99
1000	61	93	79	50	89	8,00
1200	51	94	81	51	89	7,98
1500	69	93	78	82	93	8,00

St. 29. VII 31 61°0′ N 37°55′ W n. b.

1	9,50	34,90	26,98	6,91	108	8,17
10	31	92	27,02	95	108	18
25	19	92	04	88	107	17
50	6,70	35,03	50	65	98	05
75	5,61	03	64	65	96	04
100	87	09	64	58	95	06
200	29	03	68	56	94	05
300	4,78	34,97	70	65	94	04
400	53	97	74	58	93	7,98
500	13	93	74	75	94	98
600	3,94	92	75	50	90	97
700	78	92	76	47	89	98
800	62	92	78	53	89	96
900	50	92	79	53	89	95
1000	45	93	80	64	91	94
1200	29	92	81	71	91	96
1500	04	91	84	78	92	98

St. 30. VIII 1 60°7′ N 40°23′ W n. b.

1	8,25	34,64	26,97	6,93	106	8,16
10	57	92	18	85	105	15
25	37	96	20	88	105	16
50	...	95	...	70	...	08
75	7,74	97	26,31	71	101	10
100	20	97	40	65	99	09
200	5,94	99	57	55	95	05
300	4,96	97	68	54	93	04

St. 31. VIII 1 60°5′ N 40°30′ W n. b.

1	3,72	29,01	23,08	8,75	115	8,28
10	5,40	33,85	26,74	7,46	106	13
25	7,73	34,84	27,21	6,89	103	15
50	6,74	94	28	75	102	12

St. 32. VIII 3 61°50′ N 51°26′ W n. b.

1	6,65	33,61	26,40	7,90	115	8,14
10	51	34,18	87	68	112	12
25	5,93	48	27,18	32	106	07
50	66	74	41	10	102	04
75	...	83	...	6,85	...	02
100	5,37	87	55	83	98	7,99
200	4,99	96	66	71	95	97
300	64	96	70	70	94	97

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
St. 33. VIII 4 63°55′ N 53°0′ W 67 m						
1	6,10	32,16	25,32	8,13	116	8,26
10	21	17	32	36	119	23
25	1,92	33,00	26,40	7,81	101	14
50	17	43	80	63	98	08
60	41	57	89	80	100	04
St. 34. VIII 4 63°56′ N 52°47′ W 42 m						
40	1,79	32,91	26,33	8,10	105	...
St. 35. VIII 6 64°35′ N 53°20′ W 45 m						
1	3,66	32,57	25,91	7,83	106	8,16
10	34	57	94	64	103	14
25	39	33,00	26,27	60	102	12
40	2,66	12	43	57	100	00
St. 36. VIII 6 65°5′ N 53°12′ W 48 m						
1	4,50	32,91	25,90	7,57	105	8,16
10	13	93	26,15	57	104	13
25	3,48	33,02	28	57	102	10
40	2,01	38	61	70	100	02
St. 37. VIII 6 64°53′ N 52°55′ W 349 m						
1	4,55	31,71	25,13	7,58	104	ca.8,20
10	57	32,54	80	66	105	20
25	3,06	54	94	81	104	18
50	2,31	88	26,27	74	101	16
75	1,52	33,06	47	69	99	10
100	56	26	63	60	98	...
200	2,46	34,27	27,37	6,94	91	...
300	3,67	60	52	83	93	8,00
St. 38. VIII 7 64°33′ N 54°35′ W 260 m						
1	3,73	32,86	26,13	7,96	108	8,17
10	66	33,06	30	94	108	15
25	60	10	33	55	102	11
50	2,03	58	86	48	98	07
75	—0,44	78	27,17	85	96	07
100	2,31	34,01	18	...	...	03
200	3,60	52	46	6,94	95	7,98
250	85	69	57	80	94	99
St. 39. VIII 7 65°12′ N 54°13′ W 98 m						
1	4,31	33,08	26,25	7,66	106	8,18
10	10	15	33	62	104	16
25	3,90	15	35	75	106	18
50	1,30	42	79	08	91	03
75	17	55	90	45	95	00
90	20	64	96	47	96	00
St. 40. VIII 8 66°30′ N 54°15′ W 320 m						
1	5,16	33,21	26,26	7,39	104	8,16
10	4,62	30	39	53	105	15
25	48	29	40	72	107	17
50	3,65	33,29	26,48	7,59	103	7,15
75	1,43	62	94	46	96	07
100	0,97	75	27,07	07	90	03
200	1,88	34,14	32	6,68	87	7,98
300	2,32	31	41	62	87	97
St. 41. VIII 8 66°0′ N 56°15′ W 560 m						
1	4,80	33,13	26,24	7,27	101	8,17
10	73	24	34	29	102	18
25	3,56	33	52	33	99	18
50	—1,38	60	27,05	55	90	00
75	— 55	73	15	11	85	7,97
100	—0,51	80	18	00	85	98
200	2,92	34,49	51	6,75	90	97
300	3,92	81	67	70	92	98
400	4,02	83	68	73	93	8,00
500	08	88	70	60	92	00
St. 42. VIII 9 66°30′ N 58°45′ W 675 m						
1	3,39	30,90	24,60	7,71	102	8,16
10	30	31,24	89	82	104	16
25	1,14	32,75	26,26	8,58	109	16
40	—1,00	33,42	90	12	98	08
50	— 41	55	27,01	7,71	92	02
75	— 45	64	08	19	86	7,97
100	—0,77	73	13	05	86	8,01
150	— 54	95	30	6,60	81	7,98
200	0,52	34,14	41	03	76	98
250	1,32	31	49	5,98	77	98
300	2,10	49	57	6,70	88	97
400	1,16	49	64	5,63	72	92
500	0,77	48	66	38	68	89
600	59	49	68	22	66	88
St. 43. VIII 9 66°58′ N 59°10′ W 567 m						
1	2,38	31,44	25,12	8,01	104	8,16
10	1,85	65	33	...	...	15
25	1,14	33,03	26,48	8,57	109	07
50	—1,52	10	64	7,90	94	7,98
75	— 70	30	81	60	90	98
100	64	37	87	37	87	96
200	40	78	27,20	6,78	81	93
300	—0,07	34,14	44	12	76	90
400	1,20	38	56	5,82	75	89
500	0,51	43	64	40	67	87
St. 44. VIII 13 66°27′ N 62°35′ W 270 m						
1	2,29	20,05	15,58	8,33	...	8,14
10	1,10	30,03	24,07	85	110	13
25	—1,72	31,44	25,31	85	107	15
50	— 25	32,52	26,17	29	98	14
75	— 40	75	37	7,64	90	10
100	— 53	92	50	70	91	7,90
200	— 74	33,19	73	29	86	90
250	— 68	19	73	62	90	88

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
St. 45. VIII 13 66°21′ N 61°5′ W 185 m						
1	1,09	31,51	25,27	8,40	105	...
10	0,93	56	31	50	106	...
25	83	55	30	54	107	...
50	—1,12	32,47	26,13	34	99	...
75	— 55	83	43	18	97	...
100	— 59	33,06	61	7,58	90	...
150	— 60	39	88	31	86	...
175	— 38	60	27,05	00	84	...
St. 46. VIII 13 67°19′ N 58°52′ W 1335 m						
1	...	30,75	...	8,01	...	8,10
10	2,07	74	24,61	07	103	09
25	1,43	33,10	26,51	13	104	19
50	—1,23	49	96	7,71	92	00
75	— 24	64	27,08	43	89	7,97
100	— 04	73	14	11	86	94
200	0,67	34,16	41	6.23	79	90
300	98	36	55	5,79	74	85
500	67	46	64	38	68	83
700	49	48	68	08	64	82
900	06	49	71	4,90	61	80
1100	—0,22	48	72	66	58	78
1200	— 24	48	72	45	55	75
1300	— 29	49	72	20	52	76
St. 47. VIII 14 68°28′ N 56°7′ W 350 m						
1	...	33,29	...	7,42	...	8,18
10	5,14	29	33	45	106	17
25	4,19	46	56	85	108	17
50	1,27	55	89	71	99	12
75	0,77	80	27,12	16	91	7,96
100	71	95	24	6,96	88	97
200	1,81	34,23	39	52	85	94
300	3,28	58	55	00	82	93
St. 48. VIII 14 68°28′ N 54°40′ W 360 m						
1	5,30	33,35	26,36	7,67	108	8,18
10	12	35	38	63	107	17
25	3,02	35	59	62	102	07
50	2,08	51	80	60	99	02
75	1,20	62	95	99	102	03
100	23	73	27,03	18	92	7,92
200	0,69	96	25	6,09	78	82
300	1,98	34,18	33	33	83	83
350	2,02	18	33	5,98	78	88
St. 49. VIII 15 69°13′ N 52°54′ W 810 m						
1	6,41	32,20	25,31	7,67	110	8,30
10	15	45	54	76	111	31
25	1,36	33,15	57	80	100	20
50	0,94	57	26,92	21	91	15
75	56	66	27,01	31	92	00
100	33	71	07	19	90	03
200	02	96	26	6,30	80	7,95
300	1,36	34,14	27,36	6,04	78	7,95
500	2,15	31	43	5,65	74	93
750	42	45	52	85	77	92
St. 50. VIII 15 68°12′ N 55°0′ W 40 m						
35	4,13	33,40	26,53	...	...	...
St. 51. VIII 16 67°42′ N 55°45′ W 120 m						
115	1,73	33,60	26,89	...	...	...
St. 52. VIII 16 67°27′ N 53°20′ W 40 m						
35	4.26	33,03	26,22	...	...	...
St. 53. VIII 16 66°50′ N 54°30′ W 44 m						
39	4,47	32,88	26,08	...	...	...
St. 54. VIII 16 66°30′ N 55°5′ W 180 m						
1	5,34	33,08	26,14	7,16	101	...
10	24	08	15	20	101	...
25	4,42	21	34	34	102	...
40	3,70	22	43	37	100	...
50	1,00	46	82	25	92	...
75	07	60	94	6,73	86	...
100	35	80	27,08	73	87	...
150	2,27	34,23	36	40	85	...
St. 58. VIII 18 63°39′ N 55°1′ W 1110 m						
1	6,41	33,78	26,57	7,26	105	8,17
10	31	80	59	12	104	17
25	5,63	95	79	14	102	16
50	4,20	34,45	27.34	6,91	96	08
75	12	63	50	79	94	06
100	37	69	52	72	94	04
200	22	79	62	67	93	04
300	34	83	64	65	93	05
400	50	90	68	59	92	04
500	30	90	70	60	92	04
600	24	90	71	61	92	04
700	05	88	71	61	92	03
800	3,92	87	71	53	90	03
900	78	87	72	48	89	02
1000	61	87	74	32	87	01
St. 59. VIII 18 63°41′ N 54°6′ W 1155 m						
1	4,57	31,83	25,24	7,77	107	8,17
10	3,26	32,48	88	78	104	16
25	4,13	33,95	26.96	6,69	93	13
50	6,43	34,69	27,27	80	99	09
75	5,50	74	43	64	95	10
100	4,57	69	50	79	95	06
200	32	76	58	62	93	7,99
300	40	81	62	68	93	8,03

m	$t°$	S ‰	σ_t	O $\frac{ccm}{lit.}$	M %	p_H
St. 60. VIII 18	63°49′ N	53°25′ W	235 m			
1	4,64	31,96	25,33	7,83	108	8,21
10	2,80	32,61	26,02	8,12	107	17
25	11	33,51	79	7,26	95	01
40	61	...	...	11	94	7,99
50	59	33,82	27,00	01	93	98
75	3,35	98	07	6,99	94	98
100	30	34,11	17	80	93	8,05
200	4,94	79	54	7,06	99	07
St. 61. VIII 19	64°48′ N	52°30′ W	45 m			
1	4,85	31,91	25,27	...	...	...
10	85	92	28	...	...	...
35	2,15	32,56	26,03	...	...	...
St. 62. VIII 19	63°40′ N	52°5′ W	375 m			
1	5,12	31,62	25,00	7,58	105	8,19
10	4,78	71	11	35	102	20
25	3,71	32,12	55	72	104	16
50	1,93	97	26,37	42	96	08
75	60	33,31	68	24	93	08
100	48	49	82	19	93	03
200	2,96	34,52	27,53	6,56	89	00
300	3,64	63	55	52	90	00
350	93	69	57	51	90	03
St. 63. VIII 21	60°10′ N	50°2′ W	n. b.			
10	7,71	34,47	26,92	6,52	98	...
25	83	72	27,09	53	98	...
50	65	72	13	48	98	...
100	6,13	35,03	58	31	92	...
St. 64. VIII 22	59°17′ N	44°35′ W	n. b.			
1	4,59	32,90	26,07	7,45	103	8,15
10	5,42	33,46	43	25	102	15
25	81	66	54	02	100	16
50	4,49	34,00	85	6,98	97	13
100	3,53	49	27,45	86	94	05
300	4,99	90	62	60	94	02
St. 65. VIII 22	59°18′ N	42°49′ W	n. b.			
50	7,50	34,94	27,32	6,42	97	...
100	6,60	99	49	31	93	...
St. 66. VIII 26	59°48′ N	21°45′ W	n. b.			
1	12,35	35,23	26,72	5,94	99	8,23
10	47	23	72	92	99	20
25	45	25	72	91	99	22
50	10,83	28	27,04	16	83	12
75	01	28	16	55	88	12
100	9,34	25	27	65	89	10
200	20	25	29	38	84	09
300	8,89	25	35	72	89	08
500	12	23	46	60	84	03
700	6,87	35,08	27,52	5,22	78	7,99
900	5,93	03	60	20	75	97
1100	4,74	03	75	64	78	98
1300	32	34,97	76	95	83	8.00
1500	3,89	97	80	6,20	86	00
St. 67. IX 2	62°2′30″ N	6°41′ W	123 m			
1	9,52	35,08	27,11	6,09	96	8,11
10	50	08	11	13	96	11
20	50	08	11	14	96	10
40	50	09	12	12	96	10
60	50	10	12	06	95,5	10
80	47	10	14	06	95,5	10
100	46	10	14	06	95,5	10
St. 68. IX 2	61°52′ N	6°10′ W	115 m			
1	10,00	35,14	27,08	5,91	94	8,16
10	9,98	14	09	6,34	100	15
25	81	14	12	22	98	15
50	37	14	19	18	97	13
75	25	14	21	16	96	13
100	25	14	21	13	96	12
St. 69. IX 2	61°38′ N	5°35′ W	220 m			
1	10,80	35,14	26,94	6,37	103	8,19
10	78	14	94	30	102	18
25	9,44	21	27,23	17	97	16
50	44	21	41	08	94	14
75	7,97	23	47	10	93	10
100	75	23	51	18	93	07
200	32	23	57	08	91	06
St. 70. IX 2	61°45′ N	4°35′ W	390 m			
1	10,70	35,16	26,97	6,48	104	8,17
10	69	16	97	53	105	16
25	26	10	27,01	39	102	16
50	7,64	34,79	18	58	98	15
75	5,80	83	47	82	98	13
100	02	97	68	53	97	08
200	2,62	92	87	7,06	95	04
350	1,01	91	99	22	93	04
St. 71. IX 3	61°29′ N	2°55′ W	1350 m			
1	10,07	35,07	27,02	6,25	99	8,20
10	12,08	08	26,65	18	102	20
25	11,93	08	68	23	103	22
50	9,83	10	27,08	37	100	17
75	7,97	14	40	25	95	15
100	27	17	54	26	94	08
200	5,14	10	76	57	94	03
300	2,70	34,94	89	7,05	94	00
500	0,01	92	28,06	6,88	87	7,97
700	—0,32	92	07	84	85	97
900	— 66	...	...	...	...	...
1100	— 66	34,92	28,09	6,80	83	7,96
1300	— 98	93	11	85	83	96

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
St. 72. IX 4 61°12′ N 1°15′ W 190 m						
1	13,00	35,30	26,65	6,05	102	8,20
10	12,98	30	66	00	101	21
25	41	32	78	5,94	98	20
50	38	34	80	72	95	15
75	9,79	37	27,30	80	92	14
100	68	41	35	72	90	12
175	27	39	39	77	90	05
St. 73. IX 4 60°22′ N 1°10′ E						
1	14,23	35,16	26,27	5,92	101	8,23
10	13,78	19	40	6,04	103	22
25	24	19	43	5,86	99	24
50	9,33	25	27,27	90	93	13
75	8,08	25	47	74	88	07
100	7,67	26	55	72	86	04
200	6,75	25	66	56	82	7,97

m	$t°$	S ‰	σ_t	$O\frac{ccm}{lit.}$	M %	p_H
St. 74. IX 4 59°20′ N 3°35′ E 220 m						
1	14,84	33,78	25,09	5,95	103	...
10	72	80	12	95	103	...
25	12,80	34,43	26,01	6,15	103	...
50	9,18	35,12	27,20	04	94	...
75	24	34	36	5,88	92	...
100	04	30	37	89	92	...
200	7,48	26	57	87	89	...
St. 75. IX 10 At "Steilene" in Oslofjord 96 m						
1	16,04	14,98	10,46	5,96	94	...
10	11,96	25,48	19,24	4,07	63	...
20	9,20	29,69	22,96	51	68	...
40	6,56	33,12	26,02	3,08	45	...
60	53	40	25	06	45	...
90	40	57	39	19	46	...

Surface observations.

Date	*time*	$t°$	S ‰
$^{31}/_{7}$	5 p.m.	8,5	34,87
»	7 »	0	90
»	10 »	4	96
»	11 »	7,7	87
$^{1}/_{8}$	1^{30} »	—0,5	27,03
»	5^{30} »	7,8	34,63
$^{21}/_{8}$	6^{45} p.m.	8,10	34,52
»	8 »	10	47
»	10 »	05	58
»	12 »	3	52
$^{22}/_{8}$	2 a.m.	8,1	34,43
»	4 »	0	56
»	6 »	7,1	00

Date	*time*	$t°$	S ‰
$^{22}/_{8}$	8 a.m.	7,1	33,91
»	10 »	5,6	32,90
»	12 m	4,6	30
»	1 p.m.	6,1	33,49
»	2 »	4,2	08
»	3 »	5,2	60
»	4 »	7,9	34,45
»	5 »	8,9	85
»	5^{30} »	9,2	90
»	6 »	2	..
»	10 »	9	85
$^{23}/_{8}$	2 p.m.	9,8	34,60
»	11 »	8,8	76

Date	*time*	$t°$	S ‰
$^{24}/_{8}$	2 a.m.	9,9	34,79
»	6 »	10,1	88
»	10 »	6	90
»	2 p.m.	9	35,12
»	6 »	7	12
»	10 »	63	07
$^{25}/_{8}$	2 a.m.	7	07
»	6 »	5	16
»	10 »	11,7	28
»	2 p.m.	12	30
»	6 »	11,9	21
»	10 »	4	26

Table II. Dynamic tables giving:

Anomalies of sp. vol. ($10^5\,\delta$)
and anomalies of dyn. depth $\left(10^4\,\Delta D = 10^4 \int_0^p \delta\, dp\right)$
for standard pressures.

p	$10^5\,\delta$	$10^4\,\Delta D$
Station 40.		
0	177	0
10	164	171
20	159	332
30	153	488
40	150	640
50	148	789
60	134	830
70	120	1057
80	110	1172
90	105	1279
100	101	1382
150	89	1857
200	78	2277
300	68	3007
Station 41.		
0	180	0
10	170	175
20	158	339
30	142	489
40	121	621
50	101	732
60	97	831
70	93	926
80	92	1018
90	91	1110
100	90	1200
150	74	1610
200	59	1945
300	46	2470
400	47	2935
500	45	3395
Station 42.		
0	338	0
10	304	321
20	227	586
30	157	778
40	117	915
50	104	1025
60	102	1128
70	100	1229
80	98	1328
90	96	1425
100	94	1520
200	71	2350
300	50	2955
400	46	3435
500	44	3885
600	40	4305
Station 43.		
0	288	0
10	266	277
20	192	506
30	152	678
40	146	827
50	140	970
60	133	1107
70	126	1236
80	122	1360
90	120	1481
100	118	1600
200	86	2620
300	65	3375
400	54	4070
500	47	4575
Station 45.		
0	272	0
10	266	269
20	266	535
30	251	794
40	224	1031
50	198	1242
60	189	1436
70	180	1620
80	172	1796
90	165	1965
100	158	2126
200	100	3416
Station 46.		
0	339	0
10	337	338
20	215	614
30	139	791
40	125	923
50	111	1041
60	105	1149
70	100	1252
80	97	1350
90	95	1446
100	93	1540
200	69	2350
300	56	2975
400	50	3505
500	45	3980
600	44	4425
700	43	4860
800	41	5280
900	39	5680
1000	38	6065
1100	37	6440
1200	37	6810
1300	35	7170
Station 54.		
0	188	0
10	187	188
20	175	369
30	166	539
40	162	703
50	122	845
60	118	965
70	114	1081
80	110	1193
90	105	1301
100	100	1403
150	74	1838
Station 58.		
0	149	0
10	147	148
20	133	288
30	113	411
40	93	514
50	74	598
60	69	669
70	65	736
80	61	799
90	60	860
100	59	919
200	50	974
300	49	1023
400	48	1072
500	46	1119
600	46	1165
700	46	1211
800	47	1257
900	47	1304
1000	45	1350

HYDROGRAPHICAL INVESTIGATIONS IN THE NORWEGIAN SEA OFF MÖRE 1925—1928

BY

ERIK MARTENS

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Introduction.

The west coast of Norway that south of Cape Stadt stretches in a north by south direction, deviates at this point to N.E. South of Stadt the isobath for 100 fathoms runs parallel with and at a little distance from the coast, but north of the cape it deviates from the coast, a broad shelf being formed whose slope against the great depths of the Norwegian Sea is called Storeggen. About 100 nautical miles N. of Stat the 100 fathoms isobath nears the coast once more. A profile in a north-westerly direction from the lighthouse of Björnsund at the estuary of the Romsdalsfjord would, in the first place, show a water depth of under 200 m. up to about 50 miles from land, then an abrupt increase of depth, so that these 10—15 miles farther out would reach 1000 m., to increase slowly afterwards until the depth, at 200 miles from land, would be about 2000 m. Along this profile, Professor Hjort has had, during the years 1925—1928, repeated hydrographical sections made. Sections over Storeggen have been made, as a rule, during spring and summer at intervals of about 14 days, and to about 200 miles N.W. of the lighthouse at Björnsund, a section has been made every year. The hydrographical observations were carried out by Dr. J. Ruud from m.s. "Morild". Water samples were taken with water-bottles of a model used on board the research ship "Michael Sars" and fitted with two reversible thermometers (Richter) and were stored in bottles supplied with rubber-tight china stoppers and examined later, on land, by means of chlor-titration. Oxygen samples were treated after Winkler's method with titration on land within the days immediately after the samples had been taken. The concentration of hydrogen-ions was determined on board by means of the colorimetric method of Mc. Clendon.

In order to complete this hydrographical material by current measurements an expedition supplied with current-meters was undertaken with s.s. "Skagerak" in August 1927. Both vessel and instruments were placed at the disposal of the expedition by The Swedish Hydrographical Biological Commission. In this expedition, apart from Dr. Ruud and the writer, participated also Dr. O. Nybelin who collected plankton samples and assisted to the hydrographical observations.

At the stations outside the shelf the hydrographical observations were made in the manner mentioned before, but for the work over the shelf, water-bottles of the model "Laboratoire Hydrographique" (isolating) were used, supplied with thermometer from Fr. Schmidt. Oxygen samples were titrated at once, on land, by Dr. Nybelin while the salinity samples were titrated during the autumn at

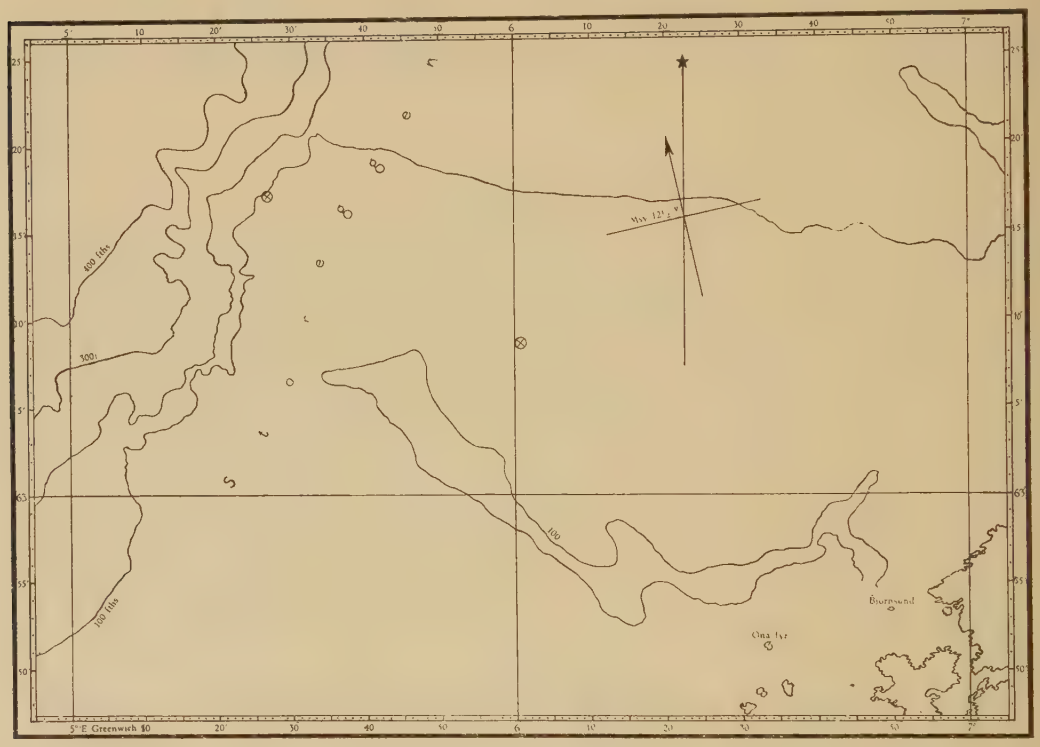

Fig. 1. As to the situation of some of the stations mentioned in this paper attention is also drawn to the Fig. No. 1 in the paper of H. H. Gran in this volume.

the Gothenburg University College Oceanographic Institution by Mrs. D. Pettersson. The outfit for current-measurement consisted of three automatic current-meters after O. Pettersson and a system of buoys and anchors for suspending of meters after G. Ekman[1]). For a more complete description of Professor Pettersson's instruments and Dr. Ekman's anchoring system, we refer to the papers mentioned. We shall here only devote a few words to this measuring method.

[1]) O. Pettersson: Photographisch registrierender Tiefenstrommesser für Dauerbeobachtungen. Svenska Hydr.-Biol. Komm. Sk. V.

G. Ekman: Zur Technik der Strommessung. Svenska Hydr.-Biol. Komm. Sk. V.

See also: H. Pettersson: A recording current meter for deep sea work. Quart. Journ. Roy. Meteor. Soc. Vol. XLI, no. 173.

The photographic registering current-meter consists of a cylinder hermetically closed and supplied with two parallel rudders and loosely suspended by means of ball-bearings. Under the cylinder, there is an anemometer wheel which by means of magnetic coupling drives a glass disc within the cylinder, in which there is also a compass. The glass disc and the compass dial with a smaller diameter are suspended concentrically. The glass disc periphery is divided into 48 numbered parts and the compass disc periphery has likewise numbers round its edge for every 10th degree of arc. Attached at the encircling brass cylinder, there is under these two discs an electric lamp which by means of clock-work is made to light once

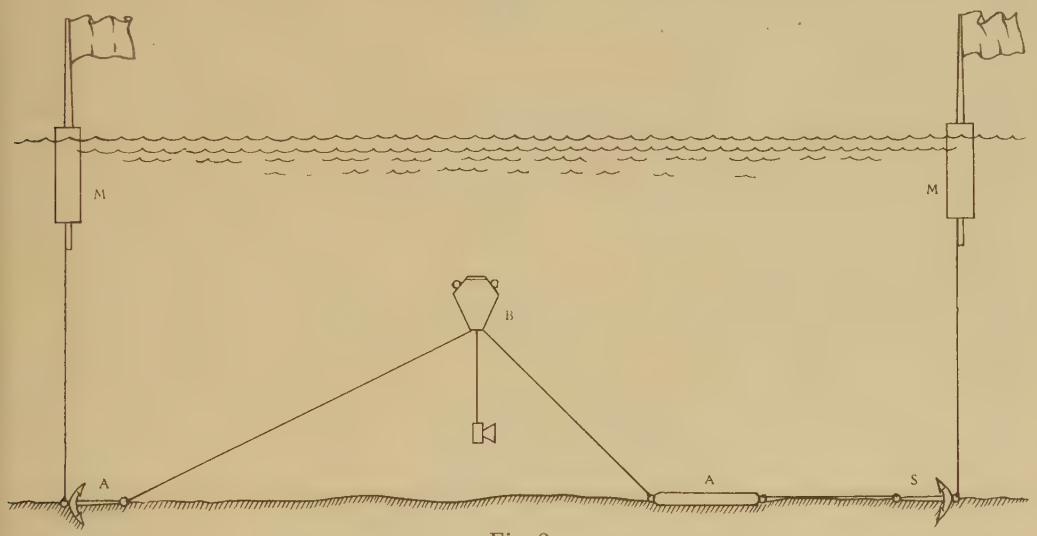

Fig. 2.

every half hour, so that one part of the periphery of the discs is illuminated. Above this illuminated part, there is the aperture of a film camera whose film is driven by the clock-work. One can thus obtain on that film every half hour a picture, one figure of which indicates the direction of the current at the time of exposure and the other figures diminished by the corresponding figure half an hour earlier, gives the measure of the medium velocity of the current during that half hour. As is also the case for other registering current-meters, this measure is uncertain as regards the number of complete revolutions, because the photographed glass disc might have done several revolutions between the exposures. But one turn every half hour corresponds to a current speed of circa 85 cm./sec. and the uncertainty is of no importance. The capacity of the instrument is so large that it can, without being seen to give out registerings every half hour for fourteen days.

This current-meter can naturally, as usual, be suspended from an anchored vessel but its practical possibilities are best employed if it is hanged in a system of buoys and anchors after G. Ekman's (Fig. 2). A current measuring instrument

is suspended in a buoy (B) that is kept down under the surface of the water about 10 m. by means of two anchors (A). When the system is placed in position, both anchors are pressed apart from one another by a third anchor (S) and the depth of the buoy (B) is controlled from a smaller boat by means of a heaving line fixed through a ring on the buoy. When the system has been properly placed this line is taken away and the position of the system is indicated by two buoys (M).

A stationary submarine starting point is then obtained for the measuring of currents. The form of the buoy and its big displacement guarantee its being only insignificantly troubled by the current. It is only when the current goes at right angle against the length of the system that shiftings can be expected to occur. The buoy can, in this case be carried away with the current a short distance and bring about a false current, though very small, and be pressed down a little by this side action. This change of depth could have a marked influence on current measurements nearest the bottom. It would be possible to avoid these two error sources by anchoring the buoy with three anchors (but the disturbancies appear to be too unimportant to justify the increased trouble of laying down a system accompanied by another anchor).

On board s.s. "Skagerak" there was such a system of anchors and buoys and three registering current-meters marked as follows: E 10, E 12, E 13. Of these only E 12 and E 13 were used while E 10 was kept in reserve. The photographic films given by E 12 were very sharp and clear, but the films from E 13 were not quite so sharp, probably on account of the electric lamp being wrongly adjusted. It is one of the weak points of the photographic method that one dare not develop on board, in rather primitive darkroom, a film containing all the results of observations. A mistake can very well remain unnoticed and uncorrected during a whole expedition. The indistinctness in the pictures taken by E 13 has, however, not been very important, and practically all observations made could be used.

The photographic films were read after their arrival by Mr. B. Otterstedt, assistant at The Swedish Hydrographical Biological Commission and the author. The material of observation is reproduced in Table III. This material is particularly appropriate for a discussion of the tidal currents, a discussion that it has not yet been possible to make on account of lack of time.

Variations with short Periods.

Connection between Mass Distribution and Velocity Distribution.

Before passing to a general discussion about the hydrographical conditions within the explored sea-region, let us first study what importance can be ascribed to each observed station. The hydrographical condition over the Shelf must be expected to be very changeable, and it is practically impossible to obtain an

instantaneous picture of any large region. We must therefore first study to what extent the combining of the different stations as sections can be justified. We shall later on study the question as to how far such a section can be considered as representing the conditions prevailing during a long period.

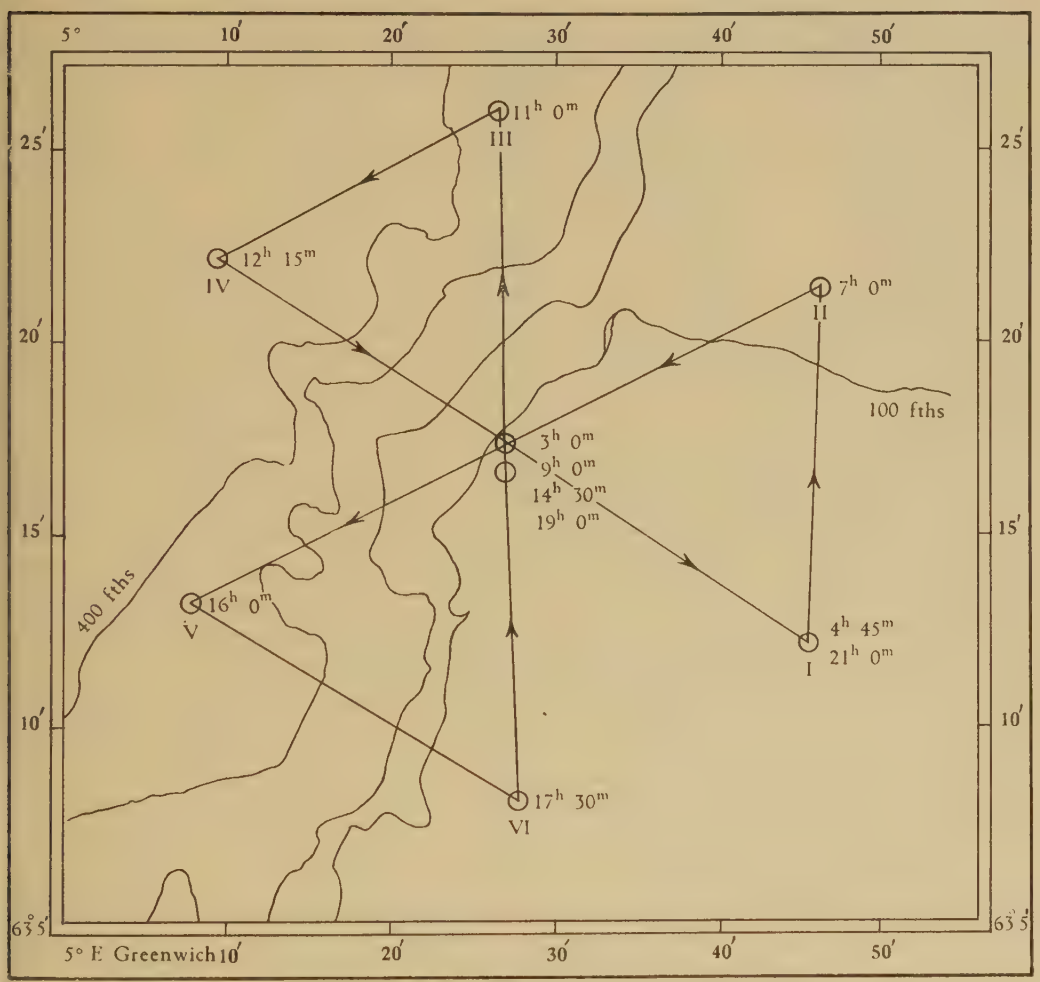

Fig. 3.

On the 8th of August, a system of 2 current-meters was placed on the furthermost edge of the shelf at a depth of about 150 m. (63°17′ N. 5°27′ E.). That system was placed as near the continental slope as it appeared possible to secure a safe anchoring. About 5 miles farther in a N.W. direction the depth was found to be 700—800 m. That system was taken up, examined and placed out again on the 14th of August. The E 13 was placed at a depth of 15 m. and the E 12 at a depth

of 135 m. The 15th of August hydrographical observations were made at six stations placed in a circle round the current-meter system. The position of the stations is shown by Fig. 3 and the following records, containing also the times (GCT) of the beginning of observations at the various stations.

		Number in Table II:							
Station	0	163, 166, 169, 172	63°17′ N.	5°27′ E.	time	3h00m	9h00m	14h30m	19h00m
—	I	164, 173	63°12′ N.	5°45′ E.	—	4h45m	21h00m		
—	II	165	63°21′ N.	5°46′ E.	—	7h00m			
—	III	167	63°26′ N.	5°26.5 E.	—	11h00m			
—	IV	168	63°21.5′ N.	5°9′ E.	—	12h15m			
—	V	170	63°13′ N.	5°8′ E.	—	16h00m			
—	VI	171	63°8′ N.	5°26′ E.	—	17h30m			

Stations I—VI are situated at an equal distance from each other along the circle around 0 with a radius of 9 miles. The distance of the stations from one another is thus, throughout, 9 miles. The observations started at 3 o'clock at the current-meter station, and the stations were then taken in the following order: 0—I—II—0—III—IV—0—V—VI—0—I. The weather was, during the day, fine with a wind alternating between E. and N.E. and with a strength of 1—4 (Beaufort). The choice of the stations and the order adopted were meant to give, during the shortest time possible numerous observations over the largest region possible around the current-meter. Each third station having been taken at the current-meters, secure positions are thus obtained for the stations around same, together with a survey over the changes occurring at the current-meter station itself. Let us in the first place direct our attention on these latter.

In the following two tables temperature and salinity observations at station 0 will be found.

Temperatures, August 15th, 1927. 63°17′ N. 5°27′ E.

GCT m.	3h00m	9h00m	14h30m	19h00m
0	14.38	14.16	14.28	14.17
10	14.10	14.10	14.10	12.72
15	..	12.99	11.48	10.00
20	11.91	8.60	9.36	8.50
30	9.78	7.11	7.38	6.96
40	8.48	6.80	7.57	6.79
50	8.58	6.75	6.74	6.72
60	8.63	6.86	6.76	6.80
80	8.26	7.57	6.91	7.08
100	7.71	7.42	6.91	7.29
135	7.54	6.58	6.82	7.45
Bottom.....	7.58	7.60	7.58	7.45
	146 m.	156 m.	172 m.	157 m.

Salinities, August 15th, 1927. 63°17′ N. 5°27′ E.

GCT m.	3^h00^m	9^h00^m	14^h30^m	19^h00^m
0	32.18	32.36	32.36	32.38
10	32.39	32.36	32.39	32.77
15	..	32.61	33.28	33.66
20	32.95	33.78	33.68	34.23
30	34.28	34.20	34.13	34.33
40	34.67	34.38	34.31	34.40
50	34.87	34.42	34.52	34.42
60	35.10	34.65	34.67	34.69
80	35.19	35.05	34.83	34.88
100	35.19	35.05	34.92	35.01
135	35.19	35.12	34.90	35.12
Bottom	35.25	35.16	35.21	35.19
	146 m.	156 m.	172 m.	157 m.

In spite of the strong variations of the bottom-depth, these stations are taken at a distance from one another and from the current-meter station not exceeding 200—300 m.

In the top layer, temperature and salinity observations show fairly constant figures. A comparison between the observations made from Stations I—VI (Table I) shows that the distribution of temperature and salinity is rather constant all over the studied region, and it is therefore impossible to draw any conclusion about the water changes from the constancy of the figures at Station 0. The conditions of the bottom observations are the same.

On the other hand, both temperature and salinity observations prove that the water layers at depths between 20 and 80 m. have undergone great changes during the time of observation. Similar rapid changes were observed in the Norwegian Sea by HELLAND-HANSEN and NANSEN[1]). These authors have accepted as an explanation for the variations observed that these depend upon vertical oscillations in the water layers. The changes observed at Station 0 can, however, not easily be explained as being vertical movements. At a depth of 80 m. the temperature at 3 o'clock was 8°.26 and six hours later 7°.57. Water of a temperature over 8° existed then only at a depth between 20 and 30 m. But it is evident that it cannot be the same water as that found six hours earlier at the time of observation because it has a considerable smaller salinity. The observed changes must, partly at least, depend upon horizontal movements. It is now possible to examine that assumption closer, since current-measurements were automatically executed at Station 0 during all the time of observation, simultaneously with the hydrographical observations.

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[1]) HELLAND-HANSEN and NANSEN: The Norwegian Sea.
See also: HELLAND-HANSEN and NANSEN: The Eastern North Atlantic.

In order to get an idea of the course of a water particle passing the current meter, at a certain moment, a supposition must be made, because as soon as the particle has passed the current-meter its further course escapes observations. In a region like the Shelf of Storeggen where such marked variations in the depth occur, the water particles at different places situated within the region may be expected to take courses which are not parallel. Let us, however, suppose that within this particularly observed region, a circle with a radius of 9 miles, the water particles at the same depth at every moment move in parallel courses. A particle then continuously moves parallel with the current simultaneously observed at Station 0 and trajectories of the particles are obtained by the construction of progressive vector-diagrams. Fig. 4 and 5 represent such diagrams for the depths of 15 m. and 135 m. at Station 0 during the time of observation.

In the first series at Station 0 temperatures between 9°.78 and 8°.26 were

Fig. 4.

Fig. 5.

observed from 30 to 80 m. while the temperatures in these layers, six hours later, were between 7°.57 and 6°.75. The salinity had at the same time diminished at all these depths. An examination of the observations from the stations around I—VI shows that nearly the same water is seen at Station III at 11 o'clock. At the other stations, there is no such water. We can therefore imply that the changes at Station 0 from 3 o'clock to 9 o'clock are due to the fact that the whole water mass has moved northwards. The progressive current diagrams furnish us with further material regarding the magnitude of that shifting. A water particle at 15 m. depth that at 2^h50^m was at Station 0 has come at 8^h53^m, if our supposition about parallel motion is justified, to a point 1.2 miles N. and 0.8 miles E. of Station 0.

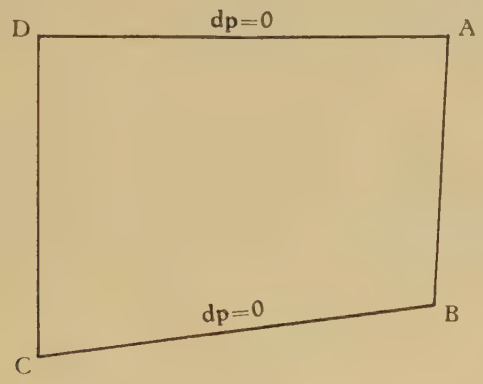

Fig. 6.

A water particle at 135 m. depth has during the same time moved to a point 1.5 miles N. and 0.5 miles E. of Station 0. The water particle of 135 m. depth was therefore on a station vertical situated 0.3 miles N. and 0.3 miles W. of the station vertical reached by the particle of 15 m. depth. In order to submit to a further test the supposition about horizontal shiftings as an explanation for the observed variations, let us suppose that the difference can be overlooked and that the whole water column observed at 3 o'clock at Station 0, has moved at 9 o'clock to a place 1.3 miles N. and 0.7 miles E. of Station 0. The observations at Station 0 made at different times at 3 and 9 o'clock might be consequently replaced by simultaneous observations made at 9 o'clock at Station 0 and at a station situated 1.5 miles N.N.E. of said Station 0. But if we have two stations lying beside one another, their different temperature and salinity distribution will, as a rule, require a certain movement of the water. By calculating the magnitude of that movement, we have a possibility of controlling the veracity of our assumption. From Professor Bjerknes' application on barocline fluids of Lord Kelvin's notion of the circulation a formula has been derived which under certain conditions gives the differences in speed necessary in order that the distribution of density will be one of dynamic

equilibrium. We shall later on examine how far our observation material seems to fulfil the presumptions forming the basis of the application of that formula, but we shall already here employ it for a discussion of the preceding problem. In Fig. 6 AB and DC are two station-verticals and we suppose that A and D are on an isobaric surface and C and B on another. Let v_1 be the speed of particles on line BC in an horizontal direction at right angle to BC and let likewise v_2 be the speed of particles at right angle to AD. Then

$$v_2 - v_1 = \frac{\Delta_B - \Delta_A + \Delta_D - \Delta_C}{2 l \omega \sin \varphi},$$

where l is the length for $AD(=BC)$, ω the angular velocity of the earth's rotation and φ the latitude for the station-verticals. Δ_A is defined by

$$\Delta_A = \int_0^A \delta\alpha_{s,t,p}\, dp,$$

where $\delta\alpha_{s,t,p}$ is the anomaly of specific volume (see following) and p the pressure. If this formula is applied at Station 0 and the one situated 1.5 miles N.N.E. of the Station 0 then

$$\frac{1}{2 l \omega \sin \varphi} = 2.75.$$

We have here expressed l in m. and if the quantities Δ_A, Δ_B ... are expressed in dyn. mm. the difference $v_2 - v_1$ will be obtained in cm./sec. In the Table II the quantities Δ_A, Δ_B, ... were given in tenths of dyn.mm. from which we get for Station 0 at 3 o'clock $\Delta_{20} = 71.90$, $\Delta_{135} = 177.15$ and at 9 o'clock $\Delta_{20} = 68.60$ and $\Delta_{135} = 167.45$. (The hydrographical observations not having been carried out at 15 m. depth at Station 0 at 3 o'clock, we have instead started from 20 m. depth.) Thus, we find $v_2 - v_1 = 2.75\,(177.25 - 71.90 - 167.95 + 68.60) = 16.2$. That figure means that a water particle at Station 0 at a depth of 20 m. would move W.N.W. at a speed of 16.2 cm./sec. compared with a water particle at a depth of 135 m. The movement during 6 hours is thus found to be 1.9 miles. The shifting calculated from the current observations is 0.5 miles towards the S.E. The agreement between the calculated and the observed shifting is not good, but — all hypotheses we had to make being taken into account — satisfying as far as the magnitude of the movements of particles is concerned, and we may consider, that this discussion of the movements of particles has not revealed any difficulty in assuming the supposition that the observed rapid changes depend upon horizontal shifting.

In the tables about temperature and salinity variations at Station 0, other variations than that discussed here are shown but are smaller, and like that one, can certainly be considered as being due to horizontal shiftings.

At first, it may seem incorrect to bring together into one section observations that are not taken absolutely simultaneously, when such a short period as 6 hours has been found to contain such important changes. But if the changes are due to a horizontal shifting, their influence on the observations is not greater than an uncertainty of a few miles in the positions of the stations, which can well be neglected in a section extending over 50 miles.

As already mentioned Professor BJERKNES has formulated an expression for the time-derivative of the circulation relatively to the earth along a closed curve, within a barocline fluid[1]). If that formula is used on a closed curve formed by two station-verticals and two isobars passing between these we obtain

$$\frac{dC}{dt} = -\int_L \alpha\, dp + 2\omega\,(v_2 - v_1)\, l \sin\varphi + R,$$

where $\frac{dC}{dt}$ is the time-derivative of the circulation, α and p the specific volume and pressure along curve L which is the path of integration, ω the angular velocity of the rotation of the earth $\frac{2\pi}{86400}$, l the distance between the station-verticals, φ their latitude (supposed to be the same for both), and R a term resulting from the friction and disappearing with it. v_1 and v_2 are the current velocities at right angle to the directions of the isobars passing horizontally through these. If we suppose that $\frac{dC}{dt} = 0$ and if moreover we overlook the friction, $R = 0$ and we have

$$v_2 - v_1 = \frac{\int_L \alpha\, dp}{2\omega l \sin\varphi}$$

but along the isobar parts of curve L, BC and DA, $dp = 0$ and then

$$\int_L \alpha\, dp = \int_A^B \alpha\, dp - \int_D^C \alpha\, dp = \int_0^B \alpha\, dp - \int_0^A \alpha\, dp - \int_0^C \alpha\, dp + \int_0^D \alpha\, dp =$$

$$= \int_0^B \alpha_{35,\,0,\,p}\, dp - \int_0^A \alpha_{35,\,0,\,p}\, dp - \int_0^C \alpha_{35,\,0,\,p}\, dp + \int_0^D \alpha_{35,\,0,\,p}\, dp + \int_0^B \delta\alpha\, dp - \int_0^A \delta\alpha\, dp -$$

$$- \int_0^C \delta\alpha\, dp + \int_0^D \delta\alpha\, dp,$$

where we have introduced

$$\alpha = \alpha_{35,\,0,\,p} + \delta\alpha.$$

[1]) Vide Selected Bibliography in Journal du Conseil.

Further p at point B equals p at point C and p at A equals at D. We have thus

$$\int_L \alpha\, dp = \int_0^B \delta\alpha\, dp - \int_0^A \delta\alpha\, dp - \int_0^C \delta\alpha\, dp + \int_0^D \delta\alpha\, dp.$$

Let us indicate the pressure at point B by p_1. Then the anomaly in the dynamic depth of the isobar p_1 at point B is expressed by $\int_0^B \delta\alpha\, dp$ and may be symbolized by Δ_B. Finally $v_2 - v_1 = \frac{\Delta_B - \Delta_A - \Delta_C + \Delta_D}{2\omega l \sin\varphi}$. If l is expressed in m. it is necessary, in order to get the velocity-difference expressed in cm./sec., to express Δ_A, etc. in dyn.mm. In the table II the dynamic depth-anomalies of the standard isobaric surfaces are given expressed in tenths of dyn.mm.

In that formula v_1 and v_2 mean speeds at right angle against the plane determined by both station-verticals. When the formula is applied to a hydrographical section we are, however, not sure that it has been taken at right angle to the real current-directions. There appears therefore some uncertainty in the application of the formula. The hydrographical observations made in the circular station-group around Station 0 on the 15th of August allow, however, the drawing of the section in any direction and thus render possible a comparison between the current-differences calculated according to the formula and those really observed. We can here draw up a chart of the relative topography (in dynamic measure) of the 20 decibar surface, compared with the 135 decibar surface. Such a chart is shown in Fig. 7. If the movement occurs so that the friction can be neglected as already supposed when term R was left out when deducing the formula, the relative current-lines in the 20 decibaric surface must correspond to the level-lines in the topographic chart.

For the difference $\Delta_{135} - \Delta_{20}$ at Station 0, we have 4 different figures: 3 o'clock 121.93; 9 o'clock 112.33; 14.30 o'clock 118.58; 19 o'clock 108.05.

The first figure markedly deviates from the others and has been left out, and the average figure 113.0 was formed from the following. On the chart, level-lines are drawn for each dyn.mm. A section of 10 miles in length at right angle to the current-lines has been drawn through Station 0. That section crosses 11 current-lines, which means that the difference $\Delta_{135} - \Delta_{20}$ for the eastern station is 11 dyn.mm. greater than for the western station. From our formula we thus find the difference between the speeds towards N. t. E. at a depth of 20 m. and 135 m. to be

$$v_{20} - v_{135} = 4.5.$$

We have not yet discussed the sign for the difference $v_2 - v_1$, but the connection between the sign and the direction of the speed difference is, as we know, that

if in the northern hemisphere the east station has greater distances (in dynamic-measure) between the isobaric surfaces than the one at the west (the sign of speed-difference being positive) this means that the top water-layers move northwards compared with the deeper ones. The calculation according to our formula shows that water-layers at a depth of 20 m. have moved in a N.E. direction at a speed of 4.5 cm./sec. compared with the water-layers of 135 m. deep. Let us now see

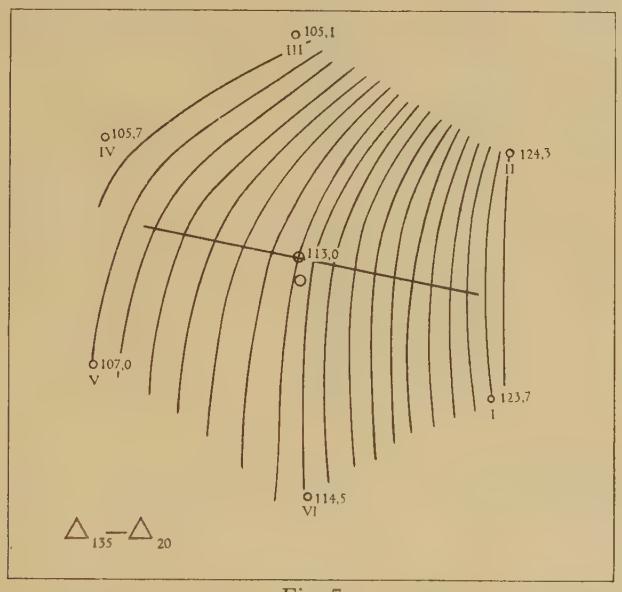

Fig. 7.

how great that difference is found to be according to the observed current-velocity. Fig. 4 and 5 represent these observations in progressive vector diagrams from 15 m. and 135 m Out of these diagrams, the average figures of the difference in current-speed between 15 and 135 m. are easily obtained at different periods of observation. These average figures are represented in the following table.

	$v_{15}-v_{135}$ cm./sec.	
	component towards N.	component towards E.
time 3^h00^m— 6^h00^m	—2.9	—1.9
— 6^h00^m— 9^h00^m	+7.9	—3.1
— 9^h00^m—12^h00^m	—22.0	+3.7
— 12^h00^m—15^h00^m	—1.0	—0.6
Average 3^h00^m—15^h00^m	—4.5	—0.5

We find, therefore, that the observations contrary to what the calculation revealed, give a smaller speed northward and eastward for the water at a depth of 15 m. than for the water at 135 m.

Before drawing any conclusion, we shall examine a few other cases where the observations from August 1927 allow a comparison between current-differences calculated from the distribution of temperature and salinity and those observed.

On the 8th of August a current-meter system was placed at Station 0 (63°17′ N. 5°27′ E.), consisting of E 13 at a depth of 16 m. and of E 12 at a depth of 135 m. On the 9th of August the following stations were taken from s.s. "Skagerak".

time 4^h00^m	63°17′ N.	5°27′ E.	Station 152 (Table I)
— 8^h00^m	63°0′ N.	5°56′ E.	— 153
— 9^h00^m	63°5′ N.	5°50′ E.	— 154
— 13^h00^m	63°00′ N.	5°24′ E.	— 155
— 16^h30^m	63°9′ N.	4°52′ E.	— 156
— 20^h00^m	63°23.5′ N.	5°5′ E.	— 157

Simultaneously the following stations were read from m.s. "Morild":

time 8^h30^m	63°15′ N.	6°6′ E.	Station 158
— 11^h45^m	63°26′ N.	6°1′ E.	— 159
— 13^h45^m	63°30′ N.	5°47′ E.	— 160
— 15^h30^m	63°33.5′ N.	5°33′ E.	— 161
— 18^h00^m	63°31.5′ N.	5°6′ E.	— 162

In the morning, the weather was good with a wind between E. and N.E., strength 2—3 Beaufort, during the day the wind increased and was in the evening E.N.E. 6.

Out of the material of hydrographical observations thus obtained one has calculated the topography (in dyn. measure) of the 20 decibar surface relatively the 135 dec. surface. In Fig. 8 the topography is represented by means of the values $A_{135} - A_{20}$ in dyn.mm. Observations are missing for the depth of 15 m. and rather than interpolate the position of the 15 decibaric surface we have formed the differences $A_{135} - A_{20}$ for comparison with current-differences between 16 m. and 135 m. $A_{135} - A_{20}$ for station 63°0′ N. 5°24′ E. differs considerably from the figures of the other stations. The depth at that station being, however, only 122 m. and the value being extrapolated, it must be left out. The figure at station 63°33.5′ N. 5°33′ E. differs also much on account of an observation of 33.42 per cent. salinity at a depth of 80 m. This figure will also be left out. In spite of these exclusions, there is still a difficulty of drawing lines for constant $A_{135} - A_{20}$, based on values 94.7 at station 63°17′ N. 5°27′ E. and 98.2 at station 63°23.5′ N. 5°5′ E. May be that the last value is due to the beginning N.E. breeze.

We obtain, however, a satisfactory picture of the relative topography if we suppose that a line from 63°10′ N. 6°0′ E. to 63°20′ N. 5°0′ E. crosses 20 equilines. The length of that line being 27 miles we find

$$v_{20} - v_{135} = 3.1.$$

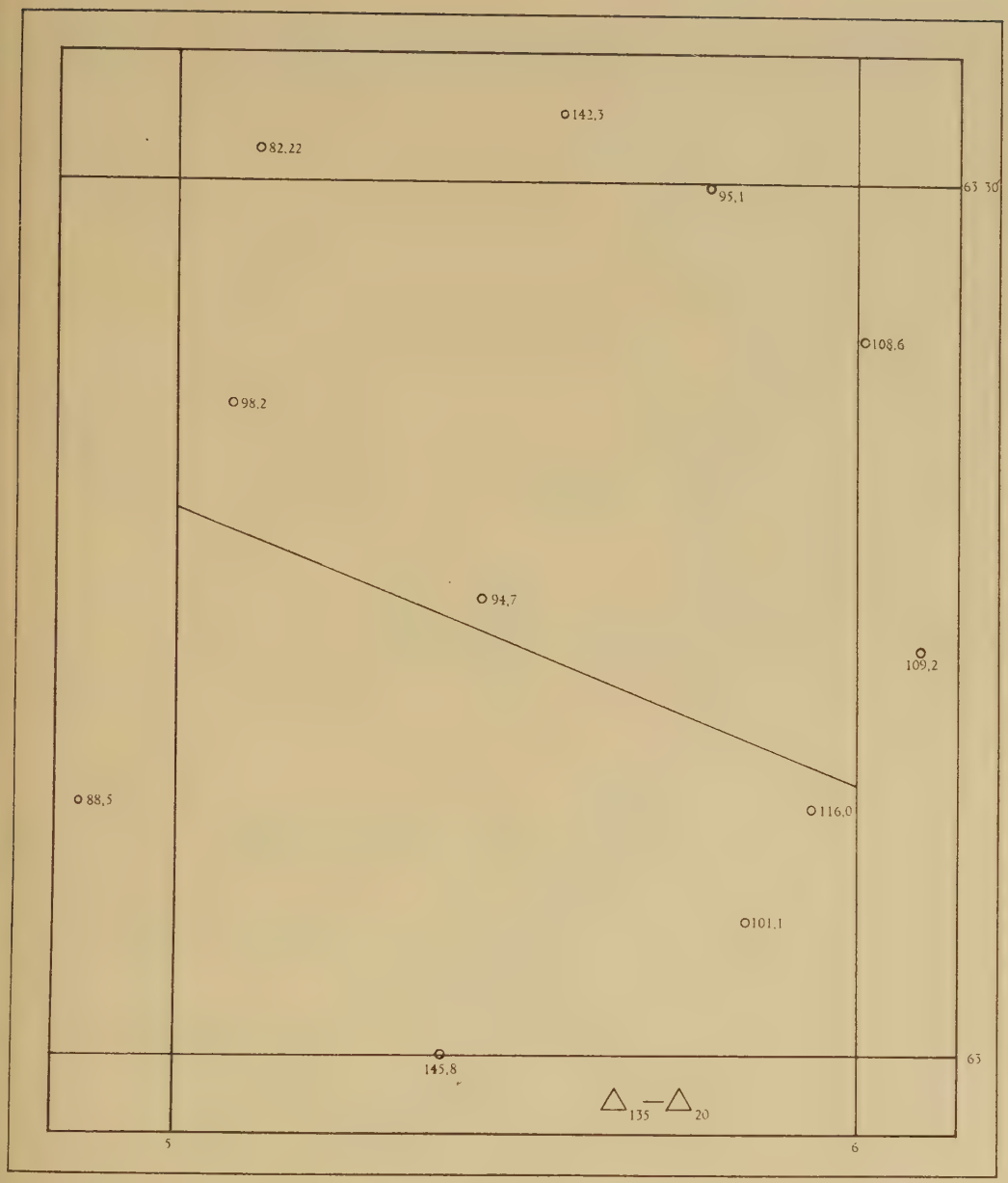

Fig. 8.

The water of the depth of 20 m. would consequently move relatively to the water at 135m. at a speed of 3 cm./sec. N.N.E. or 2.7 cm./sec. northward and 0.5 cm./sec. eastward.

The current observations from the 9th of August are graphically represented

by both progressive vector-diagrams in fig. 9 and 10. From these diagrams, it is graphically found that the water at a depth of 16 m. has had a motion relatively

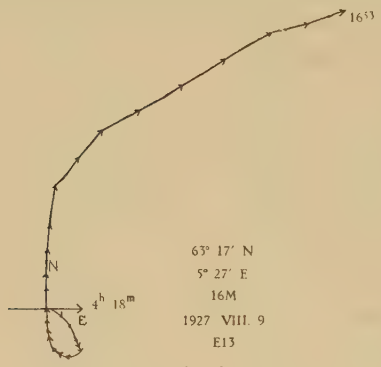

Fig. 9.

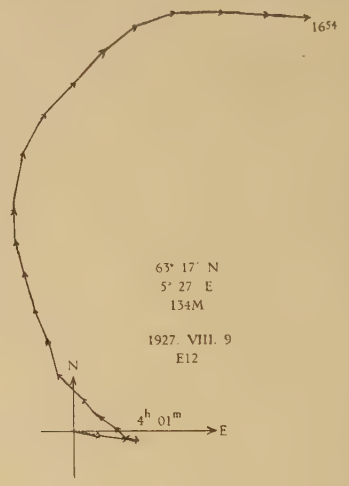

Fig. 10.

to the water at 134 m. of 3.0 cm./sec. southward and 2.6 cm./sec. eastward (average 4 o'clock to 16^h30^m). The agreement is also in this case unsatisfactory.

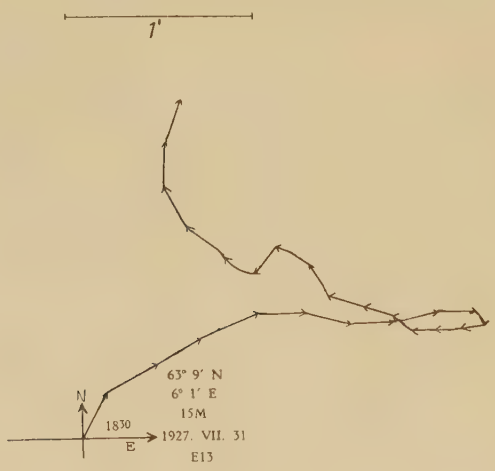

Fig. 11.

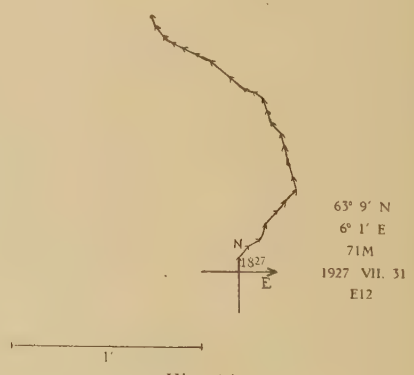

Fig. 12.

It is possible to make once more a comparison out of our observation material between current differences observed and calculated in accordance with the formula. On the 31st of July 1927 s.s. "Skagerak" made a hydrographical section from Julsund to 210 miles N.W. t. W. Björnsund (64°51′ N. 1°14′ E.). After station 17′ N.W. t. W. Björnsund (63°4′ N. 6°21′ E.) and station 32′ N.W.t.W. Björnsund

(63°12′ N. 5°51′ E.) were read at respectively 9^h30^m and 12^h00^m a current-meter system was placed at 63°9′ N. and 6°1′ E. with E 13 at a depth of 15 m. and E 12 at a depth of 71 m. At that Station E 12 worked only 14 hours but this is sufficient to give an average figure of the current during the 12^h30^m from the 31st of July at 12^h27^m to the 1st of August at 6^h50^m. The result of the current observations are graphically represented in the progressive vector-diagrams in Fig. 11 and 12. From these diagrams we easily find by means of vectorial subtraction that the water particles at a depth of 15 m. have had a speed of 1.8 cm./sec. N. and 4.4 cm./sec. E. compared with water particles at a depth of 70 m. From the hydrographical section we can calculate the current-difference of the movement, provided that this occurred in the direction N.E. t. N. We find then that the current-difference between 20 and 70 m. is 6.7 cm./sec. that is, that the water at 20 m. has moved at a speed of 5.6 cm./sec. to the north and 3.6 cm./sec. to the east relatively the water at 70 m. In this case also the agreement is not very good.

The following table gives a representation of the results of comparison between observed and calculated current-differences.

	Observed diff. cm./sec. Component towards		calculated diff. cm./sec. Component towards	
	N.	E.	N.	E.
August 15th	—0.2	—1.6	+4.0	+0.5
August 9th	—3.0	+2.6	+2.5	+0.5
July 31st.....	+1.8	+4.4	+5.6	+3.6

In all these cases, the current-speed at both depths has been directed northward. When the difference current has been negative that means, consequently, that in the upper level a lower current-speed was measured in a predominant northerly direction than in the under layer. Only in the last case (31st of July) was the velocity of the current in the upper layer greater than in the one below, but even here not so great as the calculations lead one to expect. The difference between calculated and observed current-difference is that the observations in the upper layer has given lower figures than, judging by the calculations, could be expected. Now, at all stations, E 13 was placed upmost and E 12 lowest down. An error in the determination of the constant with which the rotation figure of the meter is to be multiplied in order to obtain the current speed in cm./sec. might thus explain the discrepancy between observed and calculated current-difference, provided that that number was taken too low for E 13 or too high for E 12. That reduction factor has, however, been determined for both meters, before and after the expedition and any uncertainty in that factor for the size required is quite out of question. One could think, however, that one of the meters and more probably the upper one could be braked by filaments of jelly-fish or the like. When

the meters were taken up after the series of observations containing the measurements of the 31st of July they were, however, both free from filaments. After the measuring of the 9th of August it was found at the taking up, the 14th of August, that some filaments had been caught in the anemometer wheel of meter E 13, and after the measurement of the 15th of August, at the taking up of the 18th of August, filaments were found likewise caught in the anemometer-wheels of both E 12 and E 13. Whether these filaments had any influence on the registerings, many days before, or whether jelly-fish generally can or cannot check the fairly big and heavy anemometer-wheels, or whether they get caught in the apparatus at the taking up, it is impossible to say with any certainty. It seems, however, improbable that these jelly-fish could have had any influence on the measurings executed with E 13, so that these would have given considerably too small figures necessary for an explanation of the discrepancy between observed and calculated current-differences. Besides, earlier current-measurements of Professor Helland-Hansen[1]) show that the speed of the movement of the water northwards does not necessarily diminish with regularity from the surface to the bottom. We therefore venture to assume that our current measurements have given the real current differences and that discrepancies between measurement and calculation depend upon deficiencies in the calculation. Our calculation is also build upon two conditions which cannot be expected to be completely fulfilled, that is, that the movements of the water are stationary and friction is to be neglected. We cannot therefore expect to obtain, but very rough pictures of the movements of water over Storeggen by means of calculations with the hydrographical material according to our given formula.

Since said formula only gives differences between currents and not their absolute value, it is necessary, in order to get at the movements of water, to make supplementary assumptions. The most ordinary adoption is then that the current speed at the bottom is zero. In order to study the current condition immediately near the bottom, Prof. O. Pettersson has built a current meter placed directly at the bottom and registering the speed and direction of the current about half a metre above same. It is probable that Prof. Pettersson himself will publish the description of that apparatus and we shall therefore, here, only give an idea of the construction. The apparatus consists of an anemometer-wheel with speedometer and a rudder tightly fixed with a tube containing a luminous paint playing over a compass whose dial consists of a photographic film. The wheel, the rudder and the compass are stopped during the hauling up and sinking down of the apparatus, and only move when the apparatus is at the bottom.

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[1]) Helland-Hansen, B.: Current-measurements in 1906. Bergens Museums Aarbog 1907, no. 15, fig. 4.

The following measurements were taken with this apparatus in August 1927.

Date	Time	Position	Depth	Velocity	Direct. from
August 4th	9^h00^m	63°9′ N. 6°1′ E.	77 m.	0 cm./sec.	....
August 4th	13^h00^m	63°15′ N. 6°33′ E.	180 m.	5 —	N.W. t. N.
August 4th	16^h00^m	63°24′ N. 6°5′ E.	255 m.	4 —	E.N.E.
August 4th	19^h00^m	63°18′ N. 6°32′ E.	160 m.	5 —	N.
August 5th	3^h00^m	63°9′ N. 6°1′ E.	129 m.	5 —	N.W.

At the time when these observations were made, the instrument was still in the experimental stage and especially the direction-data are most probably very uncertain. But the figures given about current velocity show, even if these figures are uncertain as to their numerical value, that the supposition as regards an absence of current at the bottom cannot be justified.

Description of the Hydrographical Sections.

As already mentioned in the introduction, preparatory studies in the research region were undertaken in the year 1925. The positions and dates of the stations are shown in Table I. That material, as regards positions of stations or preciseness of the temperature observations is not comparable, with that of the following years, and we shall only here give the results of observations in table form and abstain from discussing same. Only the section taken outside Storeggen will be the subject of a discussion in another connection.

The hydrographical observations of the following years were executed according to the following plan. Beginning in the middle of March, a section over the shelf at Storeggen was made about every fortnight. Each section contains, as a rule, five stations named Julsund, Buadypet (5′ N.W. from the lighthouse at Björnsund), Buagrund (17′ N.W. Björnsund), Banken (32′ N.W. Björnsund) and Eggen (48′ N.W. Björnsund). The station Julsund is situated at the north estuary of the Romsdalsfjord, station Buadypet outside the estuary but in the submarine continuation of the Romsdalsfjord. The sea charts available to the author do not clearly mention anything about the depth conditions between these stations, but it seems probable that there is a small threshold between these. Station Buagrund is situated on an elevation of the shelf. The station Banken is farther out on the shelf and station Eggen, finally, lies on the continental slope itself. These section observations were continued with one or two exceptions until the end of July or the beginning of August. In 1928, however, only 4 sections were undertaken, two at the beginning and two at the end of the research period; moreover, a few observations were taken at other places, in Romsdalsfjord, which observations are reproduced in Table I but have not been discussed here.

Let us first examine the observations of the year 1926. In the section of March (Fig. 13) a salinity between 35.32 ‰ and 32.94 ‰ and temperatures between

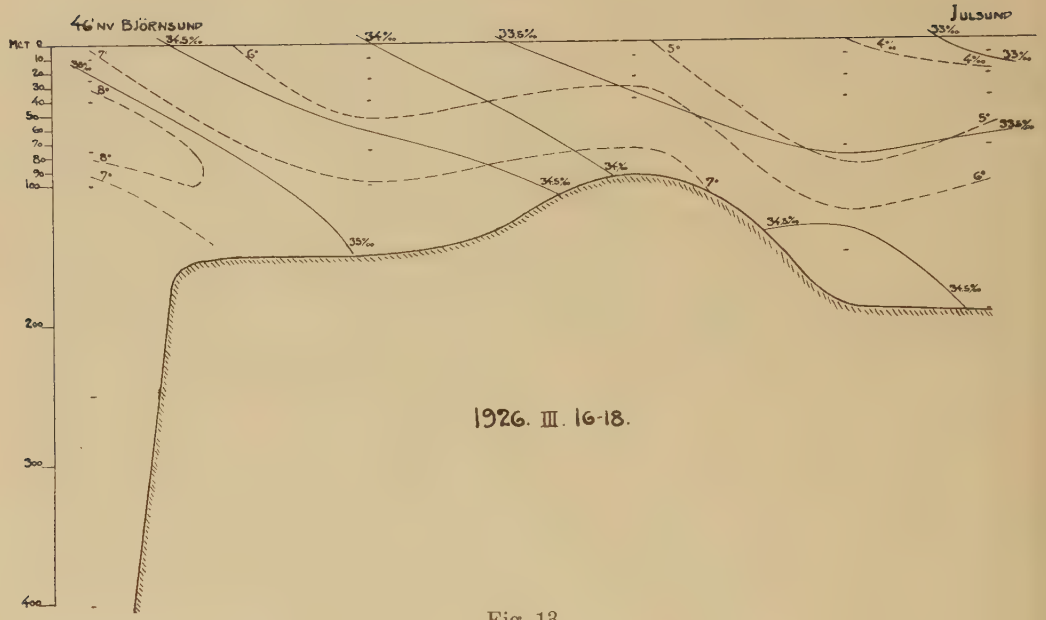
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Fig. 13.

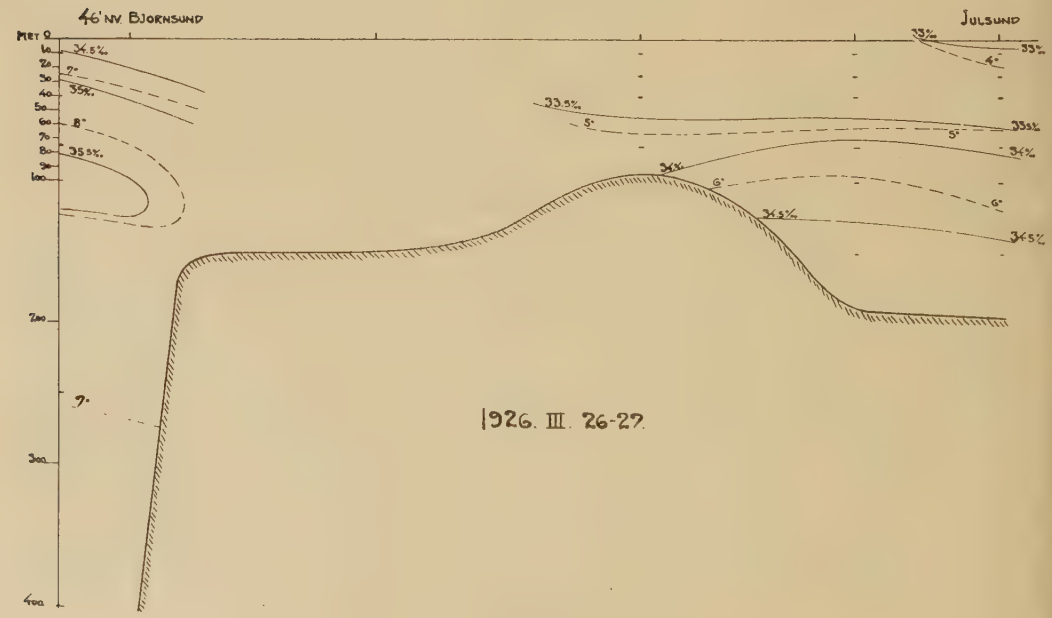
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Fig. 14.

8°.2 and 3°.7 are found. For the description of the various water-layers we shall use the terminology adopted by Helland-Hansen and Nansen (The Norwegian Sea, p. 80) and term all water with a salinity of ≥ 35 ‰ Atlantic water and the water with less than 35 ‰ salinity coast water. The coast water is a mixture of Atlantic water and water from the north-west European rivers. The water surface in the first section consists everywhere of coast water. Atlantic water has only been observed at station Eggen where it is found at all depths from 25 m. down wards. At a depth of 100 m. the salinity reaches 35.35 ‰ and the maximum of temperature amounts to 8°.21. At the stations inside Eggen all salinities are less than 35 ‰ and decrease towards the coast. The isohalines dip towards the coast. The only exception is the 75 m. depth between Buadypet and Julsund. The surface temperatures decrease inwards, from 6°.74 to 3°.7. Simultaneously, the temperatures increase from the surface inwards so that the isotherms also, as a whole, dip to-wards the coast. They have also the particularity of following the configuration of the bottom, so that at Buagrund they lie nearer the surface than at Banken and Buadypet. At the station Julsund, they again rise somewhat to the surface. The bending down of the isotherms at station Buadypet is very characteristic.

In the next section (Fig. 14), from the end of March this plunging down has disappeared but is found again in the section at the beginning of April. It is therefore probable that the section from the end of March shows a diverging picture from the average position. For the rest, this section is fairly similar to the others. At station Eggen one has, however, observed water with a salinity of over 35.50 ‰, and water with a salinity above 34.5 ‰ has spread from Buadypet to station Julsund.

In the beginning of April (Fig. 15) the Atlantic water has risen on the bank, and at the station Banken it was observed at a depth of 75 m. The bottom salinity at Buadypet had also risen so that it was 34.65 ‰ compared with what it was before, i.e. under 34 ‰. The bottom salinity at Buadypet has also increased. On the other hand, the salinity of the surface at station Julsund has decreased. Even the isothermes show a corresponding steeper and narrower course. The surface temperature at Eggen has risen to 7°.51 and the whole series at Banken shows a temperature of over 6°. The temperatures at Buagrund are, however, somewhat lower than in the section from the middle of March, but higher than these from the end of March. It is to be noticed also that in the section from the beginning of April, stations inside Banken show a somewhat higher temperature at 1 m. depth than at 10 m. That phenomenon marks the passing over to the sections read later in the year.

Already in the section from the end of April the phenomenon is fully developed (Fig. 16). In that section the 35 ‰ isohaline bends down steeper than in the preceding one. On Eggen its depth is less than 10 m. while at Banken it is found to be under 75 m. On Buagrund the bottom salinity has fallen under 34.5 ‰, at

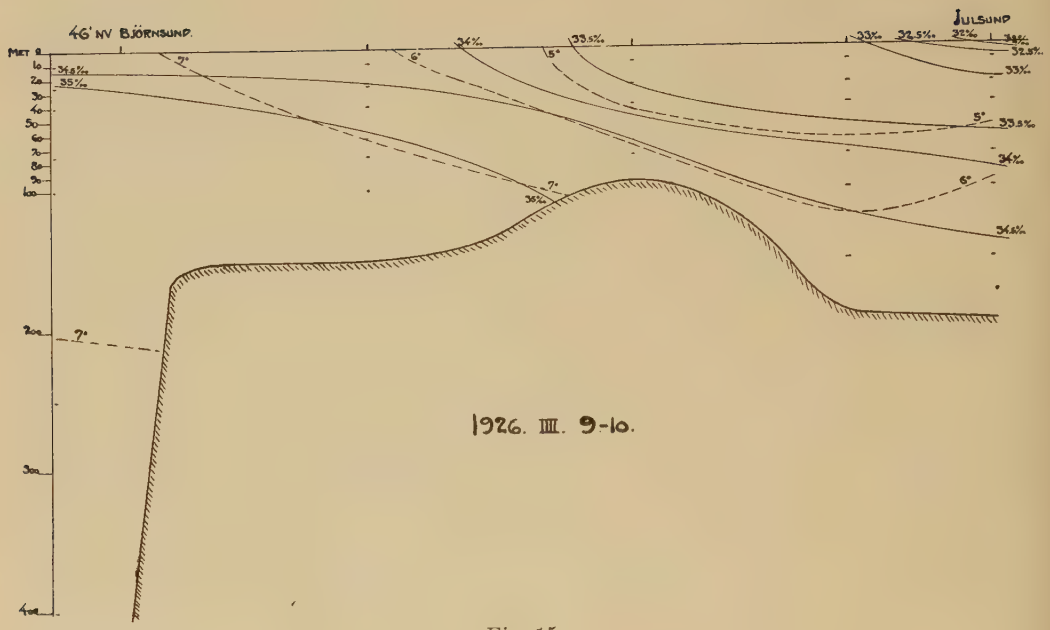
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Fig. 15.

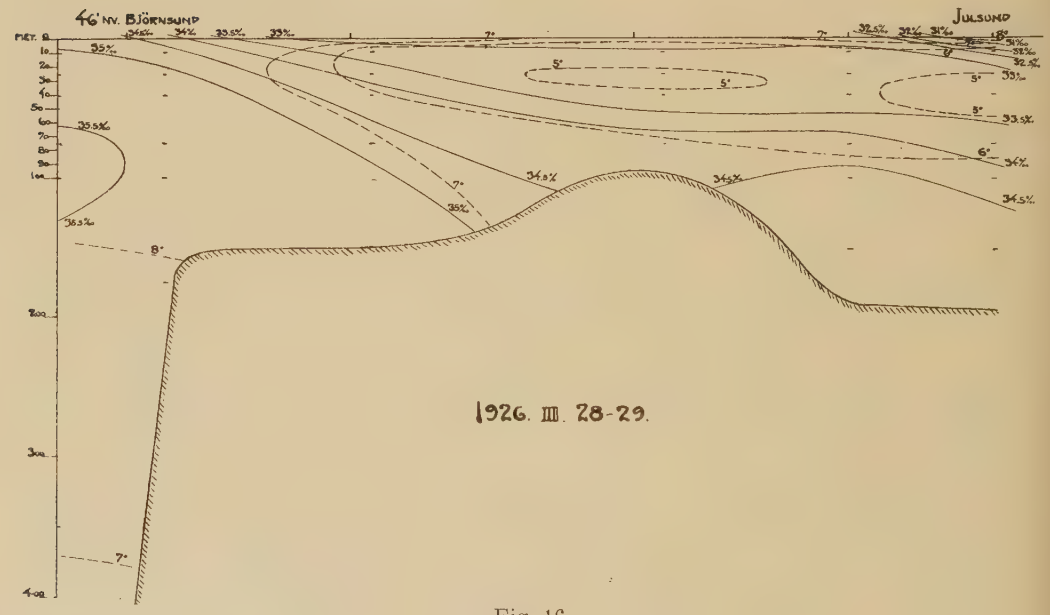
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Fig. 16.

Julsund the surface salinity is 30.41 ‰. The surface temperatures are considerably greater than temperatures at 10 m. depth, and the course of the isotherms is characterized by the intermediate temperature minima lying over Banken and at Julsund. Also at the station Buadypet, there is an intermediate temperature minimum, but not so marked. It is therefore obvious that colder water has a tendency to remain longer over banks than over greater depths[1]). The same phenomenon occurs also on the banks outside the west coast of Greenland.

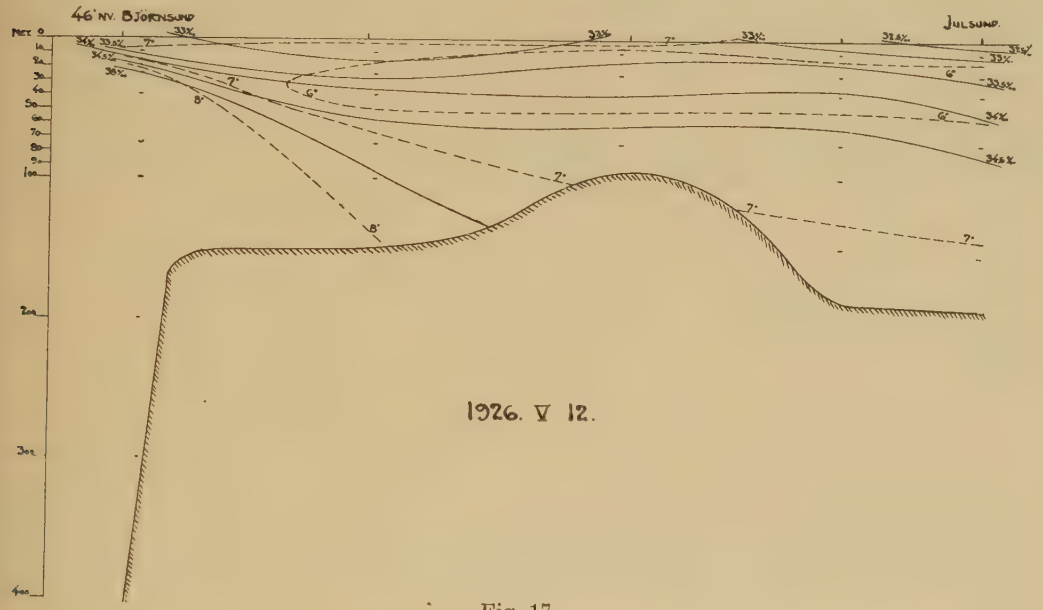

Fig. 17.

The following sections are all characterized by a tendency of the isohalines to run more parallel with the surface of the sea. In the section from the middle of May (Fig. 17) the salinity at the surface is everywhere between 32.27 ‰ and 33.08 ‰. At station Eggen 35 ‰ water can already be found at a depth of 25 m., at Banken the Atlantic water is found 100 m. deep and at the bottom of Buadypet the salinity is 34.97 ‰. The distribution of the temperature is characterized by an intermediate maximum of over 8° at station Eggen. At the stations inside Eggen, there is, on the other hand, an intermediate minimum with a temperature under 6°. The surface temperature is everywhere circa 7°.

In the section from the beginning of June (Fig. 18) the Atlantic water has penetrated further in over the bank and reaches at station Banken a depth varying between 25 and 40 m. In this section there is also Atlantic water at the bottom

[1]) cf. NANSEN: The Waters of the North-eastern North Atlantic, Hydr. Suppl. zu Band IV der Int. Revue d. ges. Hydrobiologie und Hydrographie.

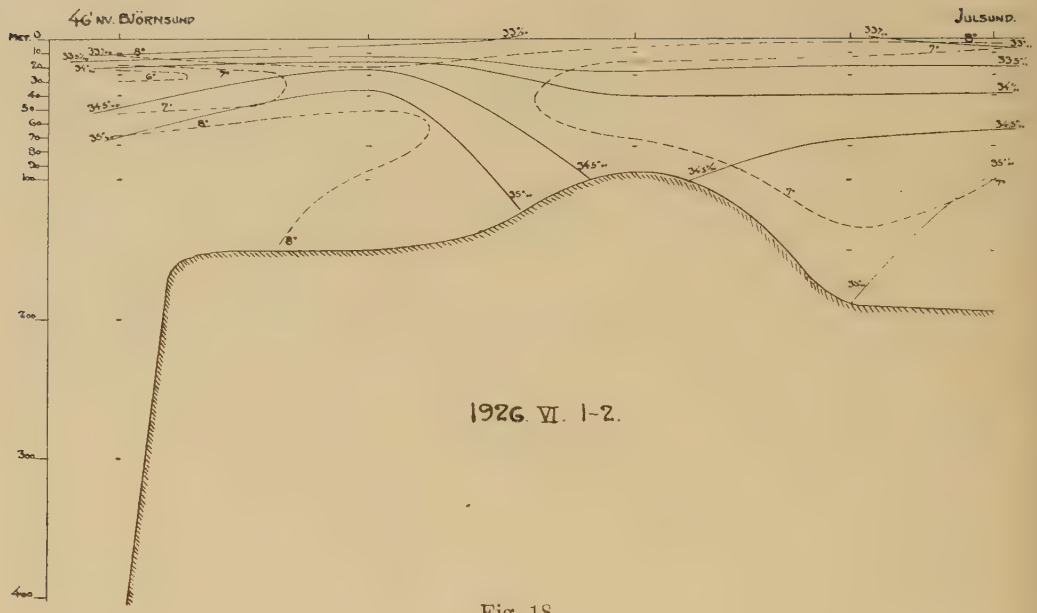
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Fig. 18.

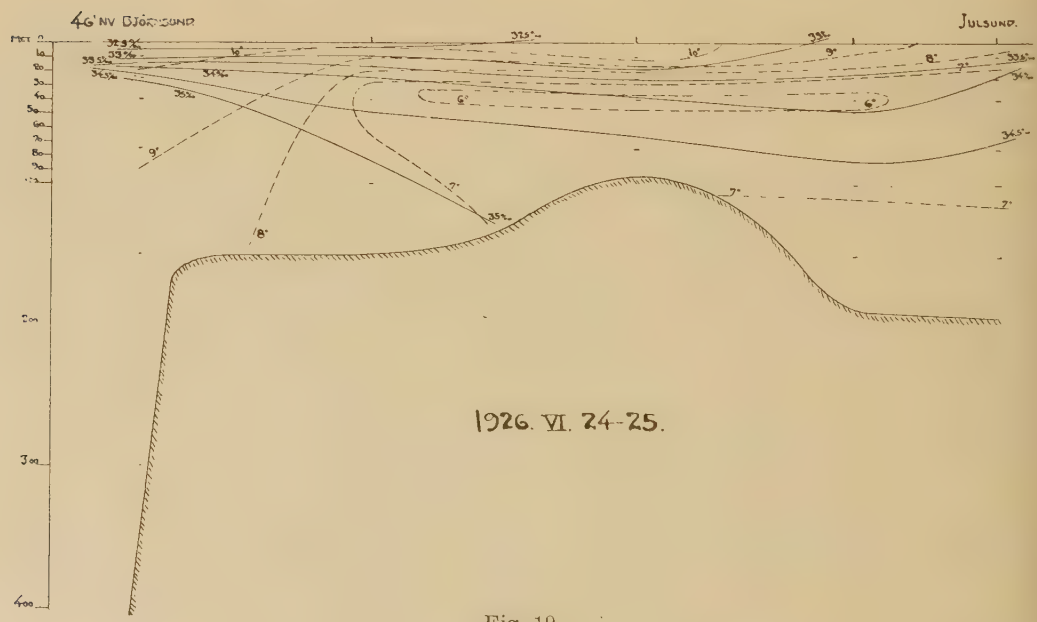
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Fig. 19.

of station Julsund. A consequence of the penetration of the Atlantic water over the bank is that the intermediate temperature maximum from station Eggen also reached station Banken. The intermediate minimum that before reached Banken finishes now between Buagrund and Banken. The warming of surface water has brought it about that there is at Eggen an intermediate minimum above the maximum.

If we now turn to the section from the end of June (Fig. 19) we find that isotherms and isohalines have again taken a more horizontal course. The Atlantic water has at station Banken sunk to a 100 m. level. The temperature of the surface-

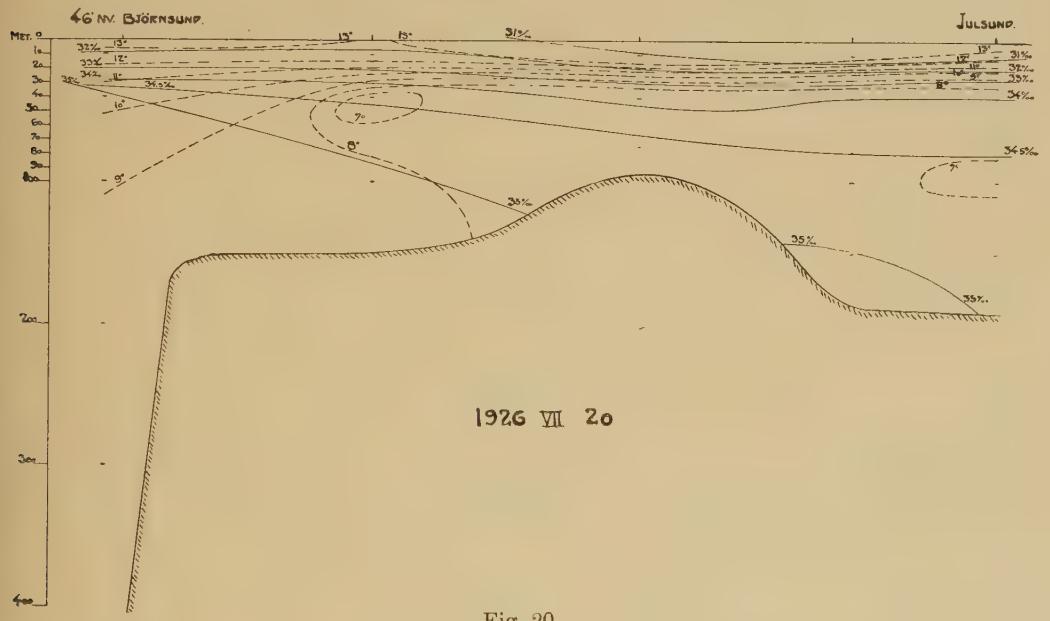

Fig. 20.

water has risen to 9°—10° and the intermediate temperature minimum has again reached station Banken. It is only at station Eggen that intermediate maxima or minima are lacking.

One month later (Fig. 20) the situation is about the same. However, the surface salinity has decreased still more, the surface temperatures have risen and the intermediate temperature minimum is only found at stations Banken and Julsund.

In 1927, the first section was already made on the 1st—2nd of March (Fig. 21). The conditions correspond, as a whole, with those of the preceding year, but there are a few differences to remark. There is at station Eggen at all observed depths Atlantic water, but the tongue of warm water that was there on the 16th of March of the preceding year has gone. The Atlantic water spreads further up on the

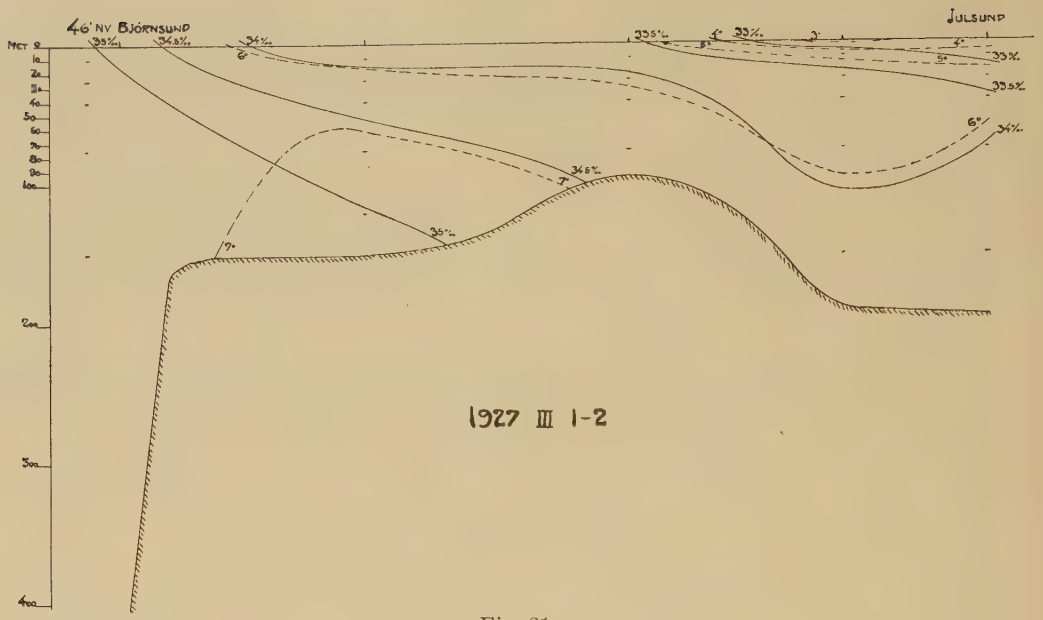
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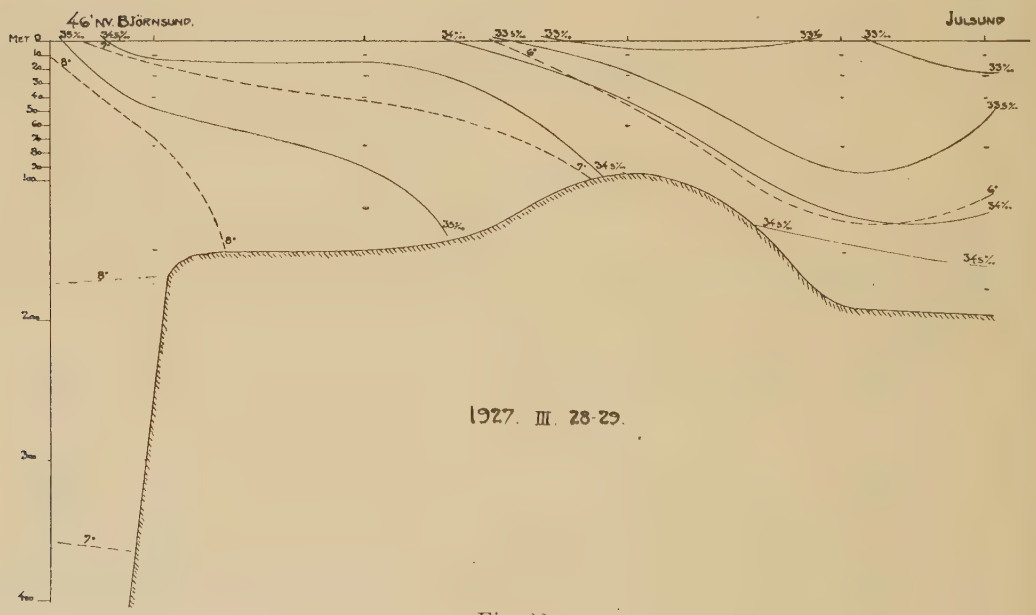
Fig. 21.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1927. III. 28-29.

Fig. 22.

shelf. At station Banken 34.97 ‰ was observed at a depth of 100 m., in 1927 35.03 ‰ at a depth of 125 m. The course of the isotherms is fairly similar to that of the preceding year. Yet the surface in the section corresponding to the water with a temperature lower than 6° is less than the same surface of the preceding year. The bottom water at station Banken is the only water that has a temperature of over 7°. Since the Atlantic water in the next section has a temperature of over 8°, that water can well be considered as a remnant of warmer Atlantic water, although the temperature at Eggen never reached the 1st—2nd of March 7°.

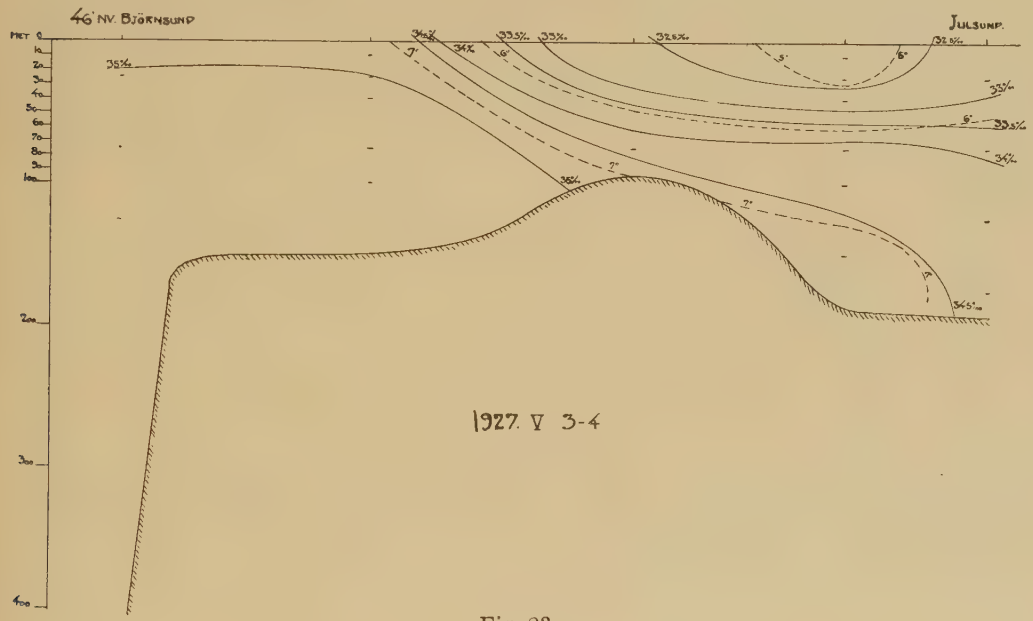


Fig. 23.

The section from the end of March (Fig. 22) has, as a whole, the same appearance as the section at the beginning of the month. The differences chiefly occur at station Eggen. Here, water of higher temperature and salinity than one month earlier are found. The salinity reaches 35.30 ‰ (cf. 35.35 in the middle of March 1926) and that water has a temp. of 8°.38. In March 1926, the maximum-temperature was 8°.11.

The next section (Fig. 23) was taken one month later, in the beginning of May. At that time, the Atlantic water has penetrated considerably farther up on the bank, and at station Banken reaches a level between 10 and 25 m. The conditions at Buagrund have, however, remained about the same. Over Buadypet a channel containing water with a salinity under 32.5 ‰ can be noticed. The isotherms also show a steeper decline towards the coast. That accumulation of coast water at the coast may be due, partly to the W. and S.W. winds that had

been blowing the preceding days with a strength of between 5 and 6, but considering that the section one month later shows Atlantic water farther up than the previous year, that circumstance may not be due only to the winds. If the section from the beginning of May 1927 be compared with the section from the end of April and beginning of May 1926, many important differences will be found. In 1926, the Atlantic water over the bank was considerably less powerful, but its temperature and salinity at Eggen were higher. Already at the end of April 1926, a distribution of temperature with intermediate minimum appears, but even

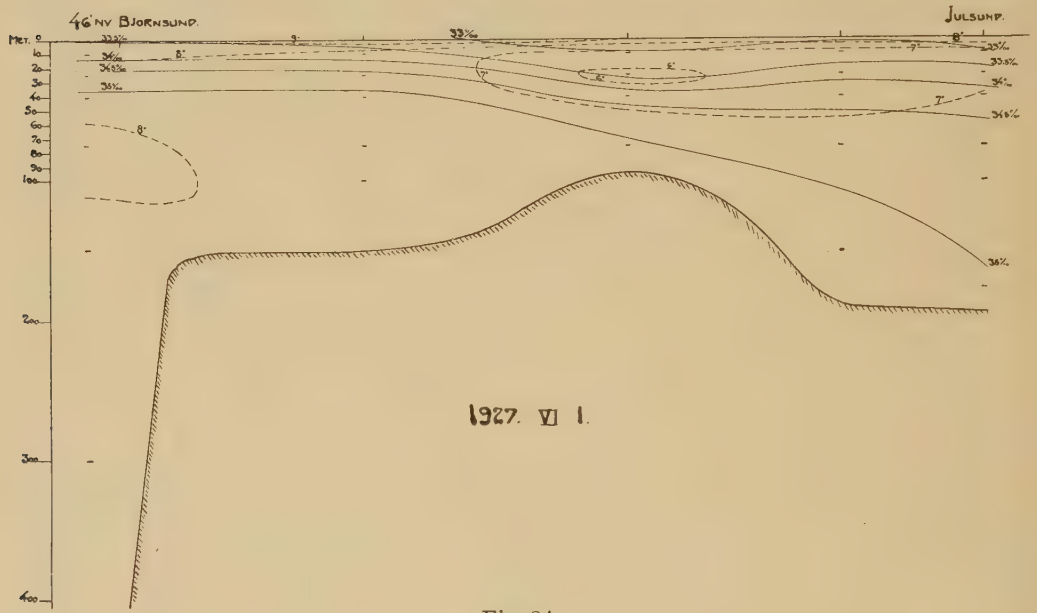


Fig. 24.

in the beginning of May 1927, the surface water does not show any increase of warmth to temperatures above those of the intermediate layers.

It is only in the section of the 1st of June 1927 (Fig. 24) that the increasing of surface temperature and intermediate temperature minimum occur, but the phenomenon appears more characterized than during the preceding year with higher surface temperatures and lower intermediate ones. In 1927, the Atlantic water has penetrated over the whole section and is found at the bottom at all stations. Earlier in the year, the Atlantic water at Eggen had a higher temperature than at the corresponding time in 1926, but in that section the contrary is the case. In the beginning of June 1926 at Eggen water of a temperature of 8°.52 with a salinity of 35.32 $^0/_{00}$ was observed, in 1927, the temperature was 8°.11 and the salinity again 35.32 $^0/_{00}$.

One month later (Fig. 25) the Atlantic water has again gone down. Its

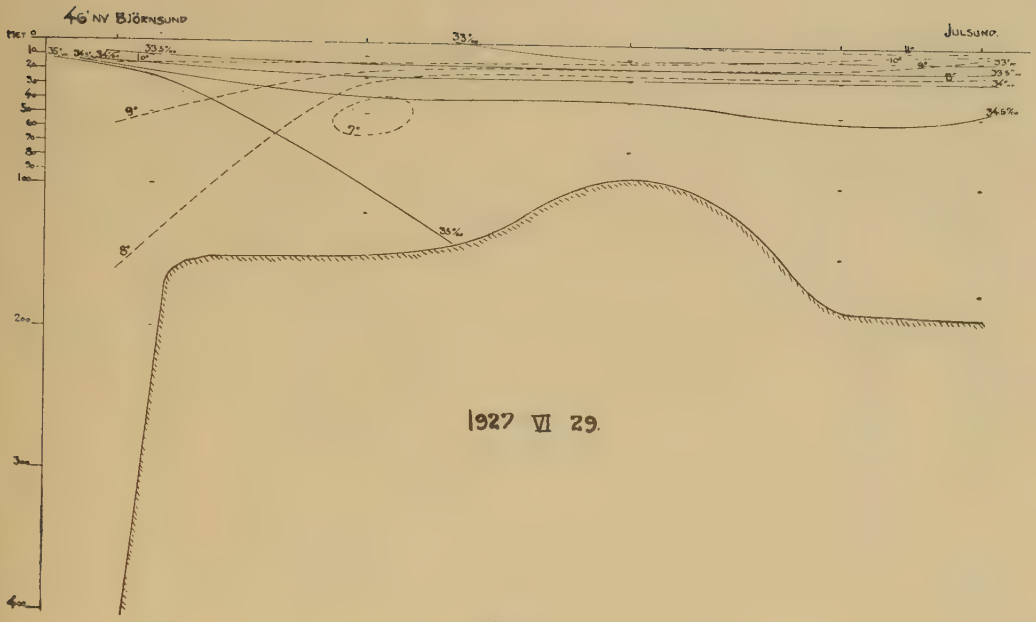
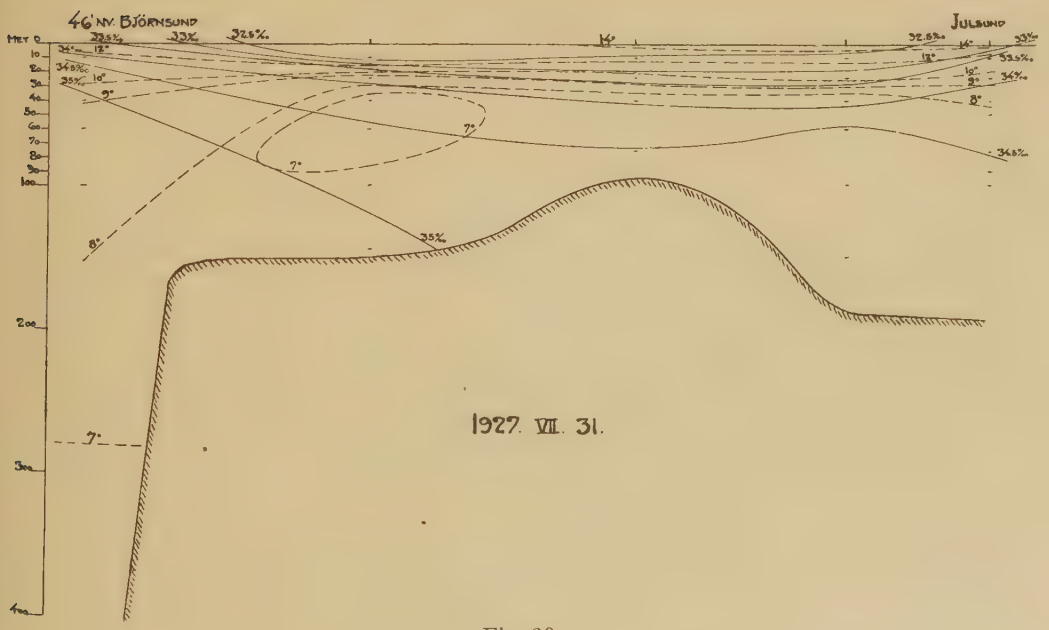

46 NV BJÖRNSUND
JULSUND
MET 0
1927 VI 29.

Fig. 25.


46 NV. BJÖRNSUND
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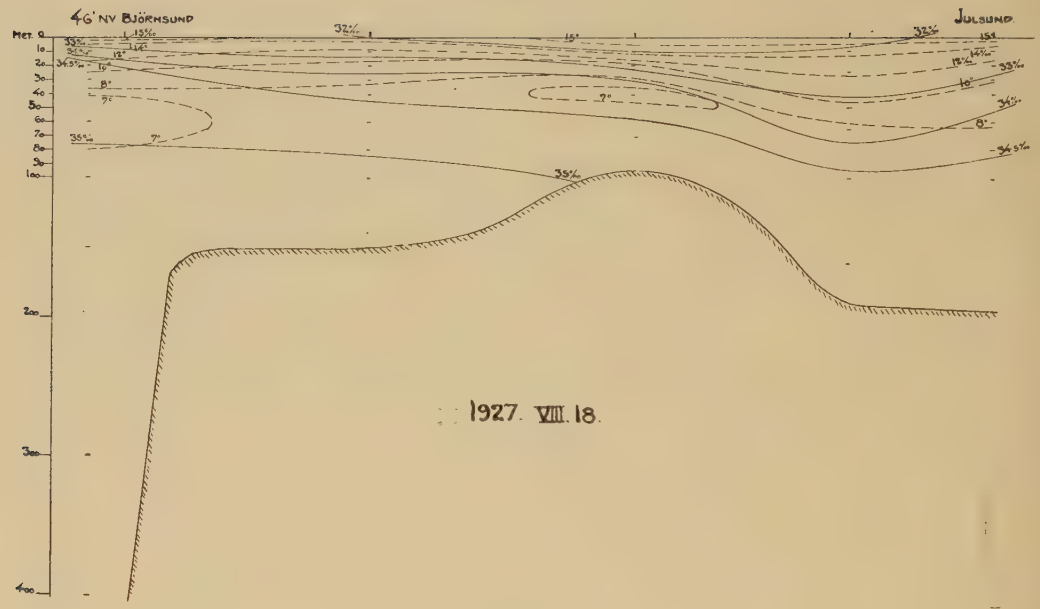
1927. VII. 31.

Fig. 26.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1927. VIII. 18.

Fig. 27.

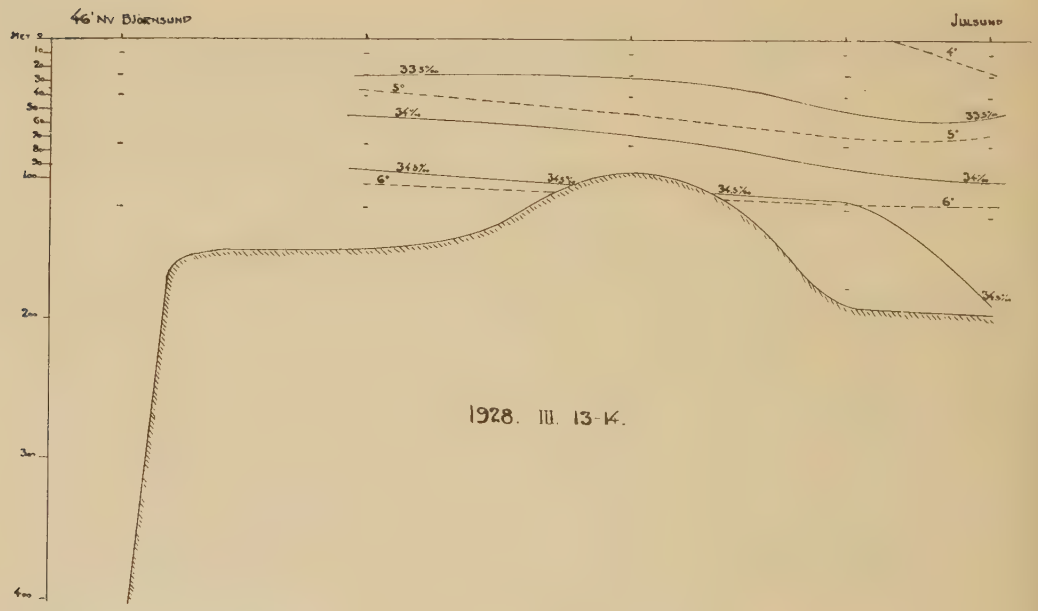
46' NV BJÖRNSUND
JULSUND
MET.
1928. III. 13-14.

Fig. 28.

temperature at Eggen continues to be lower than in the preceding year. At the surface the salinity differences are greater (33.42—27.83 $^0/_{00}$) than the year before (32.45—32.24 $^0/_{00}$). The heating from the surface has proceeded quicker than in the preceding year, so that of the intermediate minimum there are only unimportant traces at the station Banken, whereas the year before it was found at Banken, Buagrund and Buadypet.

The alteration one month later, like the year before, chiefly consists of a rise in temperature (Fig. 26).

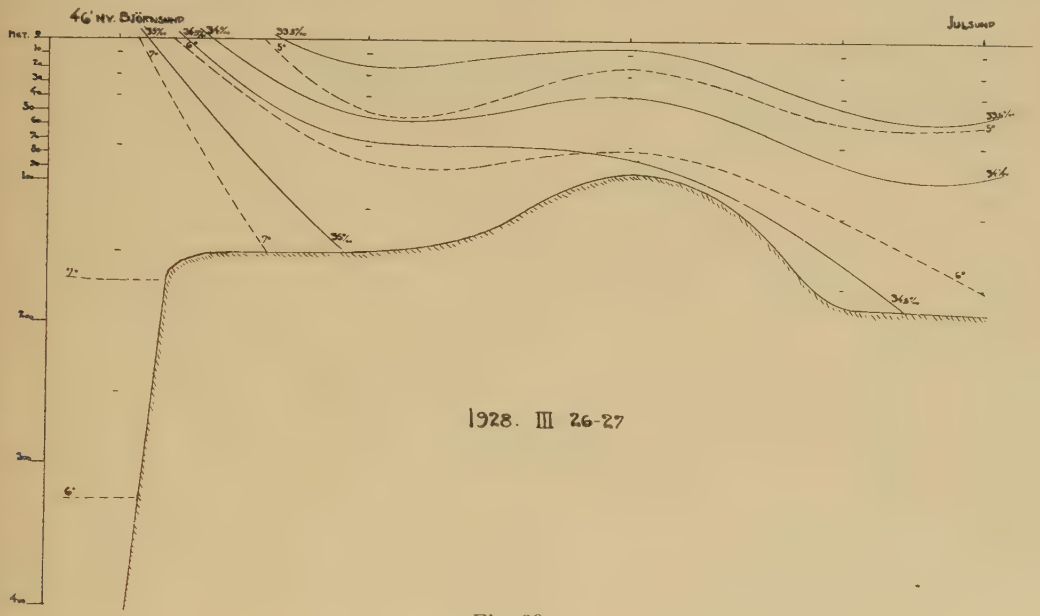

Fig. 29.

The last section in 1927, was taken in the middle of August (Fig. 27).

Let us now compare the observations made in 1928 with those of the two years before. The first section from 13th—14th of March (Fig. 28) shows a more horizontal course of both isotherms and isohalines than those of the preceding year. The surface water with a lower salinity extends further out. At the bottom of station Banken the salinity is lower than in the preceding year. All temperatures, those at the bottom of station Buadypet excepted, are lower than those of the year before.

The next section from the end of March (Fig. 29) shows a position resembling more that of the preceding year and is similar to 1926, especially as far as the water on the banks is concerned. The most striking differences from the preceding years are found over the continental slope itself. The 35 $^0/_{00}$ isohaline shows an unusual steep decline. At Eggen, the surface salinity is 35.32 $^0/_{00}$, while the bottom

salinity at Banken is only 34.83 $^0/_{00}$. Therefore, the whole water-column at station Eggen contains Atlantic water, at least down to a depth of 400 m. The temperature of that water deviates, however, considerably from that of the preceding years. While the temperature in 1926 at the surface and at a depth of 400 m. was circa 6°.5 and a temperature maximum of 8°.11 occurred between, and the temperature of the top water layers in 1927 was about 8°.30 and that of 400 m. layers 6°.80, the highest temperature in 1928 was 7°.43 and at 400 m. 5°.41. The Atlantic water therefore has had outside the bank a temperature lower by 1° than in the preceding

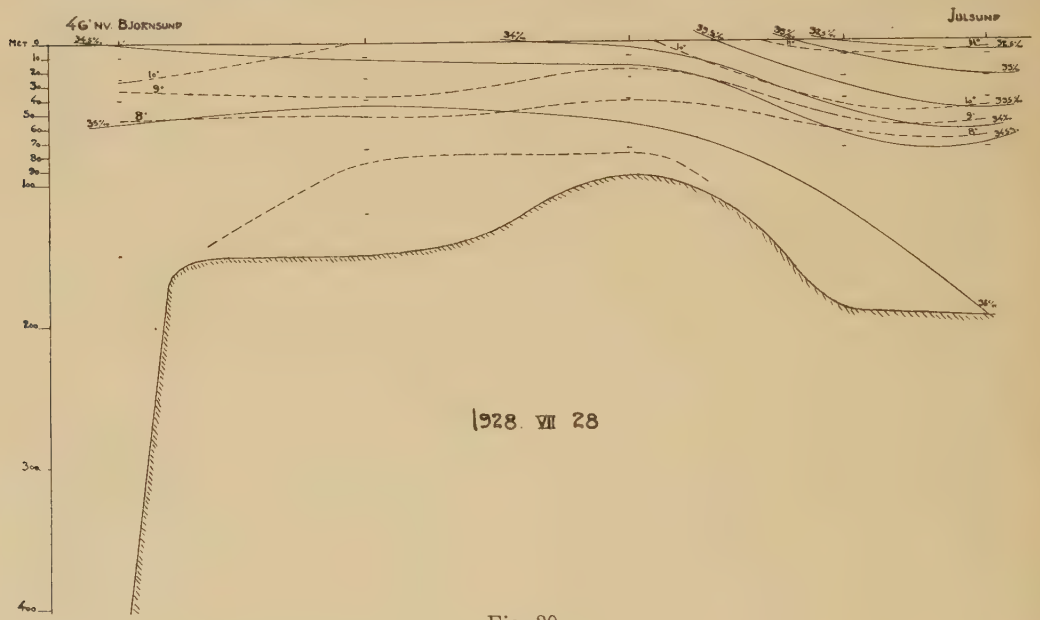

Fig. 30.

year. As however, temperatures are subject to fluctuations and as this observation stands alone, it is not here possible to ascertain whether these conditions prevailed during the whole spring.

The next section (Fig. 30) was taken on the 28th of July. The temperatures in that section are considerably lower than those of both preceding years. The Atlantic water which the year before only rose at the bottom of station Banken, in 1928 stretches over the whole region of the bank right into Buadypet and is seen at station Banken at less than 25 m. deep. The salinities at the surface are also throughout higher than those of the preceding year. The most remarkable difference lies, however, in the distribution of temperature. In 1926, the surface temperatures were about 13° and, in 1927, about 14°, but in 1928 they only amounted to about 10°. The distribution of temperature further down corresponds, however, more with that of the preceding year.

The last section was made in the middle of August (Fig. 31). At that time, the Atlantic water appears to have receded and only reaches a little inside Buagrund. However, it always occupies more space than in the preceding year. Surface salinities continue to be higher than last year's, while surface temperatures are about 2° lower.

There now remains for us to examine the sections made once every year during the summer from station Eggen up to circa 150 miles. N.W. of this station.

At station Eggen (63°20′.5 N. 5°19′ E.) the depth is about 700 m., 4 miles

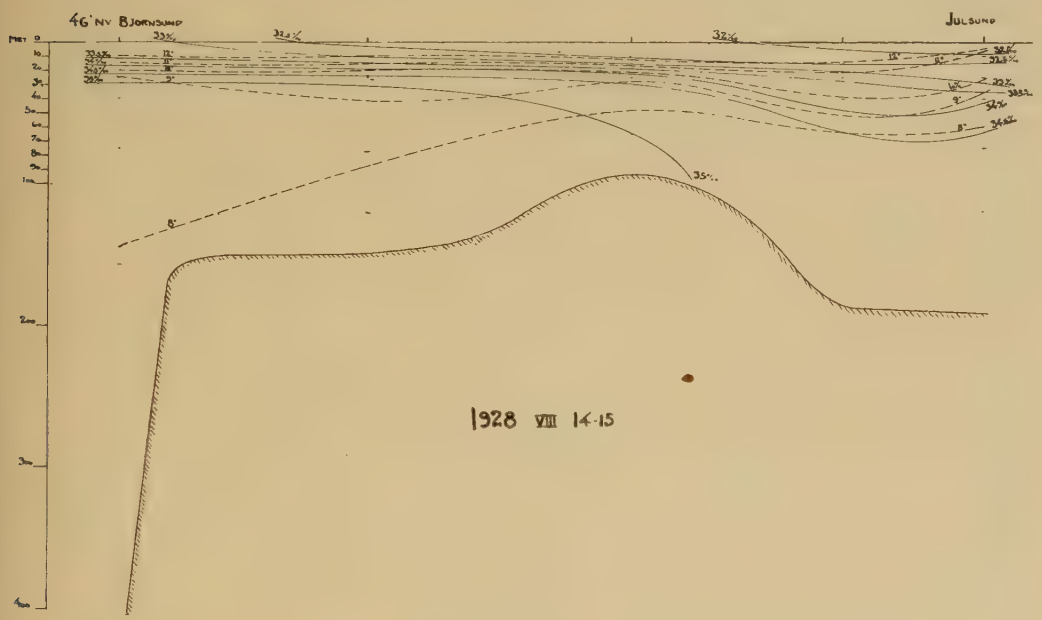

Fig. 31.

S.E. of this station the depth is only about 200 m. 150 miles N.W. of Eggen the depth is about 2,000 m. (Helland-Hansen and Nansen: The Norwegian Sea, bathymetric chart). The sections studied in the preceding part referred to the water over the shelf and the continental slope. The sections we are now going to study are made over a lower plateau with depths varying between 1000 and 2000 m.

In 1925, a section forming part of the preliminary researches was made from 52 miles N.W. of Björnsund to 174 miles N.W. of Björnsund. The observation include the uppermost 200 m. At the surface, immediately off Storeggen, there is water with a salinity of under 35 ‰. The highest salinity was observed nearest Storeggen at a depth of 100 m. (35.32 ‰). As we know, that layer of Atlantic water rests on another layer with lower salinity. That bottom water attains in the section a level of 200 m. at the outermost station only (34.91 ‰). Salinities at 50, 100 and 200 m. are at station 84 miles N.W. of Björnsund lower than the

corresponding salinity at station 52 miles N.W. and 114 miles N.W. of Björnsund. That raising of less salt and cold water is still more noticeable in the course of the isotherms. The isotherms of temperatures above 9° run nearly parallel with the surface with a slight decline downwards towards the coast. The isotherm of 9° has a similar course at the outer station, but inside 84 miles N.W. of Björnsund it steeps more abruptly. The isotherm of 8°, on the other hand, is considerably steeper and reaches at 114 miles N.W. of Björnsund a 200 m. level, to make there a pronounced curve upwards at 84 miles N.W. of Björnsund and finally disappears under the 200 m. level at the station 52 miles N.W. of Björnsund. That course of

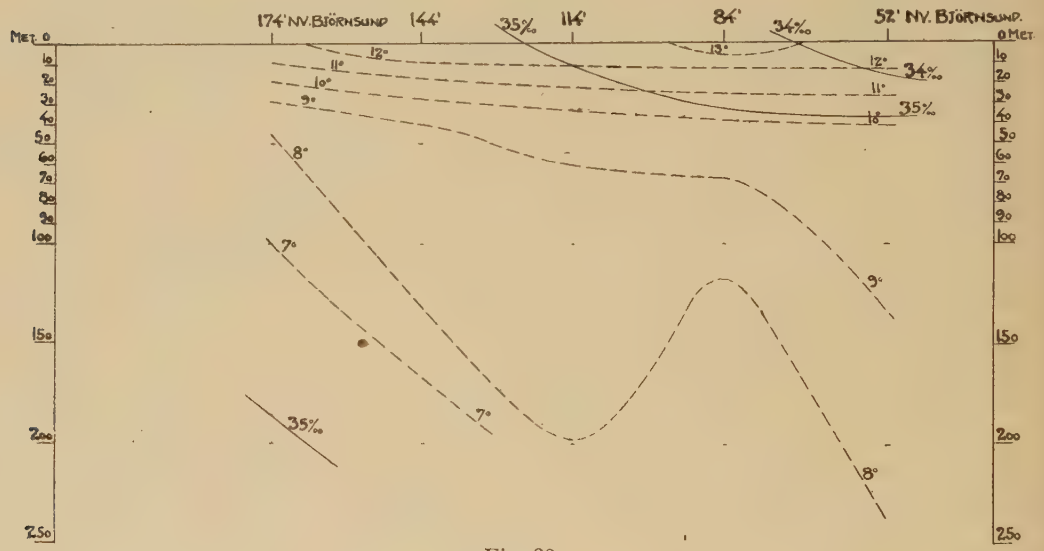

Fig. 32.

the isotherms induces one to think that the water at station 114 miles N.W. of Björnsund has a less rapid motion to N.E. than the water at 52 miles N.W. of Björnsund, in short that to the general water motion to N.E. a vortex motion is added round a vertical axis (see Helland-Hansen and Nansen loc. cit.).

The 1926 section was made two months earlier in the year (Fig. 33), and specially as regards temperatures at the surface-layers is not quite comparable with the section of the preceding year. Temperature and salinity distribution in the depth are, however, fairly similar to those of the preceding year and again represent a vortex motion with vertical axis at about 75 miles N.W. of Björnsund. The distribution of salinity at the surface is remarkable. While the salinity found at station 75 miles N.W. of Björnsund is at the surface 34.92 $^{0}/_{00}$, the corresponding figure, for the stations 45 miles N.W. and 105 miles N.W. of Björnsund are below 33 $^{0}/_{00}$. At station 105 miles N.W. of Björnsund, there is thus, as far as can be seen in the section, isolated water of lower salinity. Helland-Hansen and Nansen

have observed the same phenomenon and think it can be explained as a water-mass being detached by a whirling motion (Helland-Hansen and Nansen, loc. cit. p. 125) an explanation which is here very probable, since the isotherms indicate the existence of a vortex between that water-mass and Storeggen.

1927 section (Fig. 34) was made slightly earlier in the year than the section in 1925. That year, the observations were made down to 830 m. depth. At the surface, the coast water seems to have spread to about 150 miles N.W. of Björnsund. Like the year before, although not quite so markedly, the salinity 75 miles N.W. of Björnsund is higher than at 100 miles N.W. of Björnsund, and the ex-

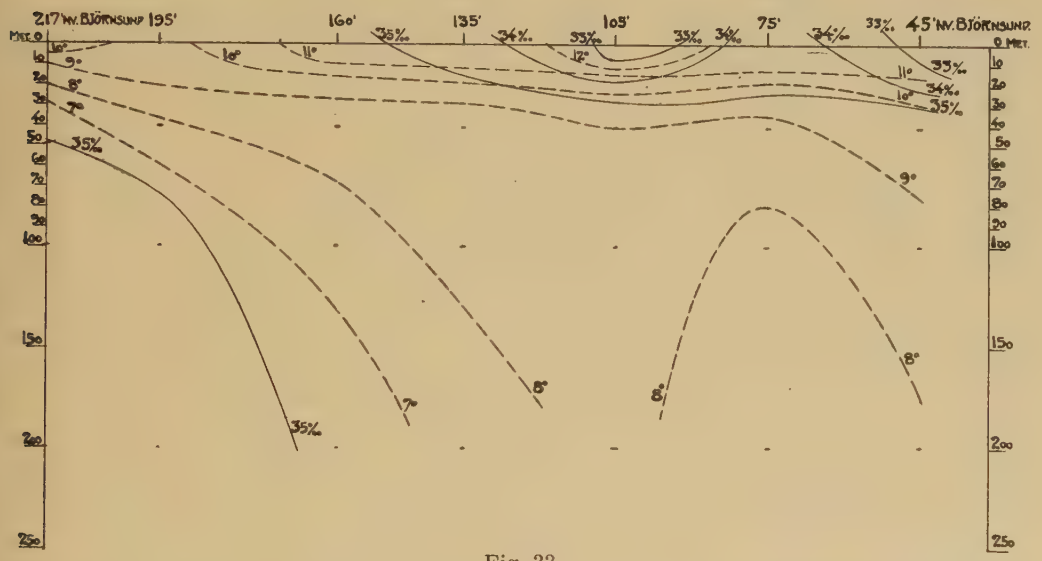

Fig. 33.

planation is evidently the same. Under the coast water, the Atlantic water flows in a layer whose thickness varies between 200 and 600 m. The highest salinity of the Atlantic water, 35.34 ‰, is met 48 miles N.W. of Björnsund at 100 m. depth. Isohaline 34 ‰ shows, as before, a decline downwards towards Storeggen, but with a visible elevation 75 miles N.W. of Björnsund. Regarding the temperature, it is to be observed, in the first place, that surface temperatures steadily keep 1—2° higher than in 1925. Isotherm 8° lies, however, throughout nearer to the surface than in 1925. Isotherm 0° runs fairly horizontally, but reproduces the curving downwards and upwards presented although in a more pronounced manner, by the isotherms lying above at stations 105 miles and 75 miles N.W. of Björnsund. The isotherm 0° lies about 650 m. deep. The water underneath, which has consequently temperatures below the freezing point has a salinity varying between 34.83 and 34.96 ‰. The course of isotherms and isohalines between 180 miles and 210 miles N.W. of Björnsund, is worth noticing and indicates that the water

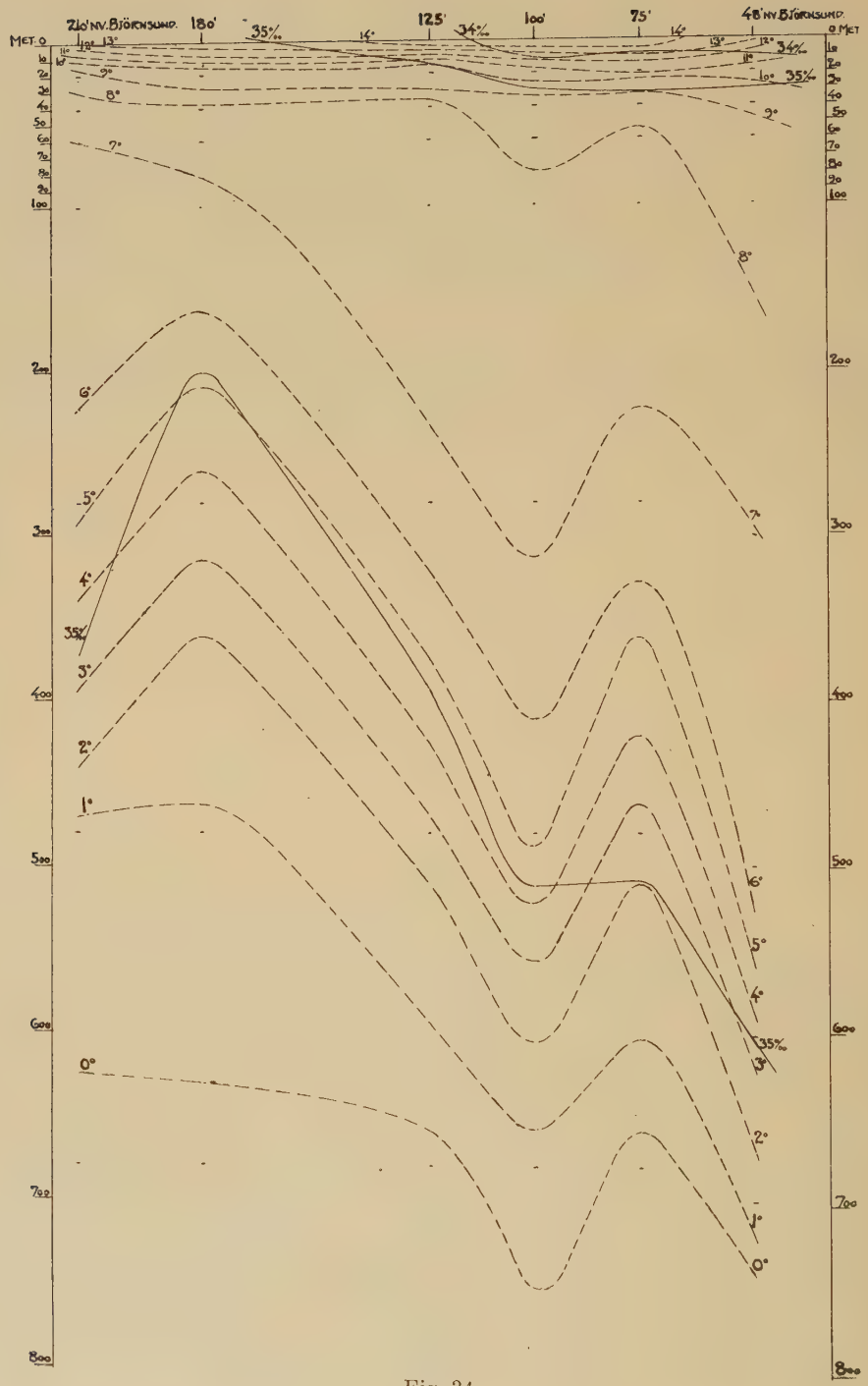
210' NV. BJÖRNSUND.
180'
125'
100'
75'
48' NV. BJÖRNSUND.
MET. 0
35‰
34‰
0°
1°
2°
3°
4°
5°
6°
7°
8°
9°
0 MET
100
200
300
400
500
600
700
800

Fig. 34.

at station 210 miles N.W. of Björnsund that lies west of the chief bulk of Atlantic water moves at less speed towards N.E. than the water found further east.

The 1928 section (Fig. 35) was taken later in the year than any of the sections of the preceding years, though with a difference of a few days only compared with 1925. As already mentioned before, temperatures in the 1925 section are, as rule, lower than in 1927 (and higher than those taken in 1926 two months earlier in the year). The temperatures in 1928 are still lower than in 1925. An exception is made, however, for the figures obtained at 100 and 200 m. depth at stations 75 miles N.W. of Björnsund (1928) and 84 miles N.W. of Björnsund (1925), where the 1925

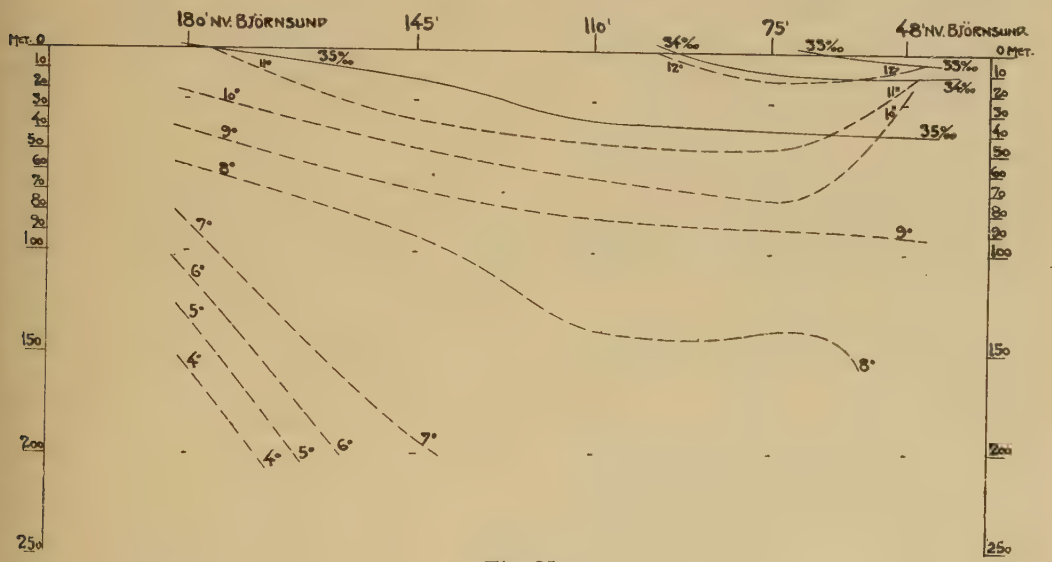

Fig. 35.

figures are lower than those of 1928. The rising of isotherms so clearly marked in the 1925 section at station 84 miles N.W. of Björnsund can hardly be traced in the 1928 section. At the surface, the salinity increases uninterruptedly from the coast outwards and it is impossible to trace any separate tongue of less saline water. This is probably due to the fact that the vortex with the vertical axis is not quite so marked. The coast water spreads, however, farther out from the coast than in any of the preceding sections. At a depth of 200 m. at station 180 miles N.W. of Björnsund, the salinity is still above 35 ‰. Both isohalines and isotherms run more horizontally than in any of the preceding years. We may therefrom drawn the conclusion that the Atlantic water, at the time when that section was read, had had a smaller speed compared with the bottom water than was the case in the preceding year, and had probably also an absolutely smaller speed. Besides, the Atlantic water in 1928 presented a lower temperature than recorded the year before.

Yearly Variations and Currents.

We have already before examined how the value of observations along a station-vertical depends upon the quick changes arising in the hydrographical conditions as shown by repeated observations. We found important probabilities for adopting an explanation, that within the investigated region the observed quick changes are due to horizontal movements for some miles. The errors of observations obtained through the fact that all stations in a section cannot be read simultaneously, and that between the first and last station, in the section, 12 to 24 hours elapse, only means uncertainty as to a mile or so in the position of stations. We can therefore state that the sections over the shelf and Storeggen form a real representation of the hydrographical situation at a certain period, even if it is connected with slight mistakes of same importance as the uncertainties of some miles or so in the positions of stations.

We must, however, devote a few words to the question as to whether such a section at a certain moment can be considered as being characteristic for a complete hydrographical average situation, a hydrographical season. The hydrographical conditions could, in a few days, present changes of such amplitude that a section would rather represent an extreme situation than illustrate the average existing conditions. In order to study this question it would, in fact, be necessary to make repeated section at such short intervals so that several sections would fall within the very period thought to be the period of changes (the word period being used without assuming that the changes are periodical). But even if the sections are made at intervals several times greater than the supposed period of changes, it will be possible, with great probability, to draw from them conclusions about the amplitude of the changes. The more sections are made the more unlikely it is that these should coincide with changes in the same phase, and, besides, if the intervals between the sections are different, the probability decreases still more. Therefore, if a long succession of sections present a regular development one from the other, we may come to the conclusion that the short-periodical changes that might be found must, however, be of small amplitudes.

In order to study the sections over Storeggen in this respect, a diagram was drawn up showing the change of temperature and salinity during the year at different places over the shelf in the various years (Fig. 36—45). If we begin here to study each curve by itself without taking into consideration the comparison existing between the curves of the various years, we find that both temperature and salinity curves show fairly great variations, especially during the months of March and May. If we compare the years 1926 and 1927 by means of the sections of the 26th of March 1926 and 28th of March 1927 (Fig. 14 and 22) the temperatures in 1926 are found to be lower than in 1927. If, on the other hand, a comparison is made by means of the sections taken one month later (Fig. 15 and 23) the situation

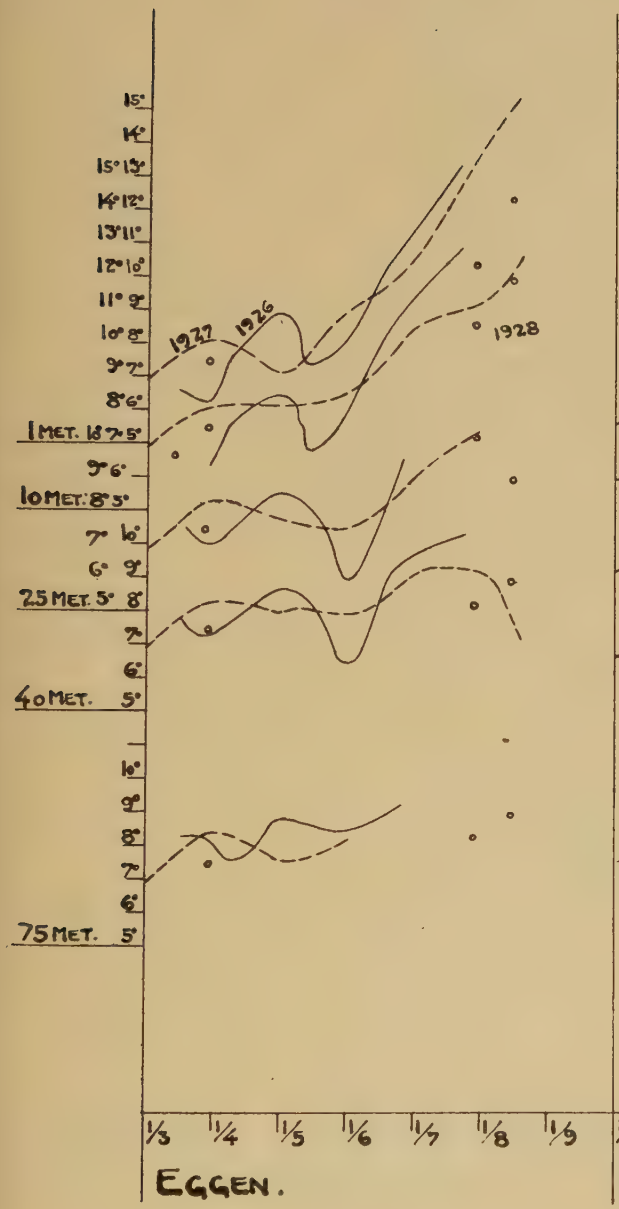

Fig. 36.

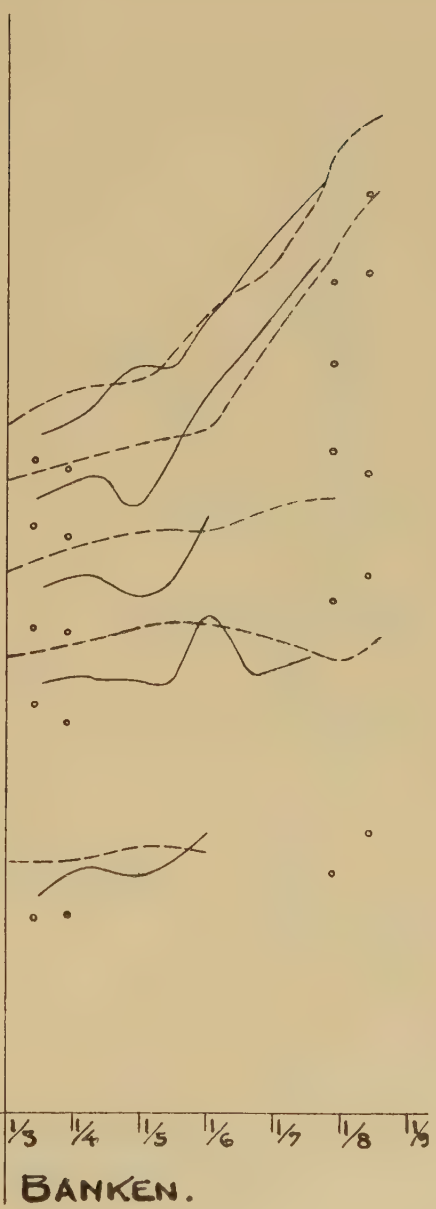

Fig. 37.

is the reverse. We must therefore insist upon the fact that the representation of the hydrographical situation obtained by means of a section, cannot so much be looked upon as representing the average situation during the time nearest to the period when the section was read.

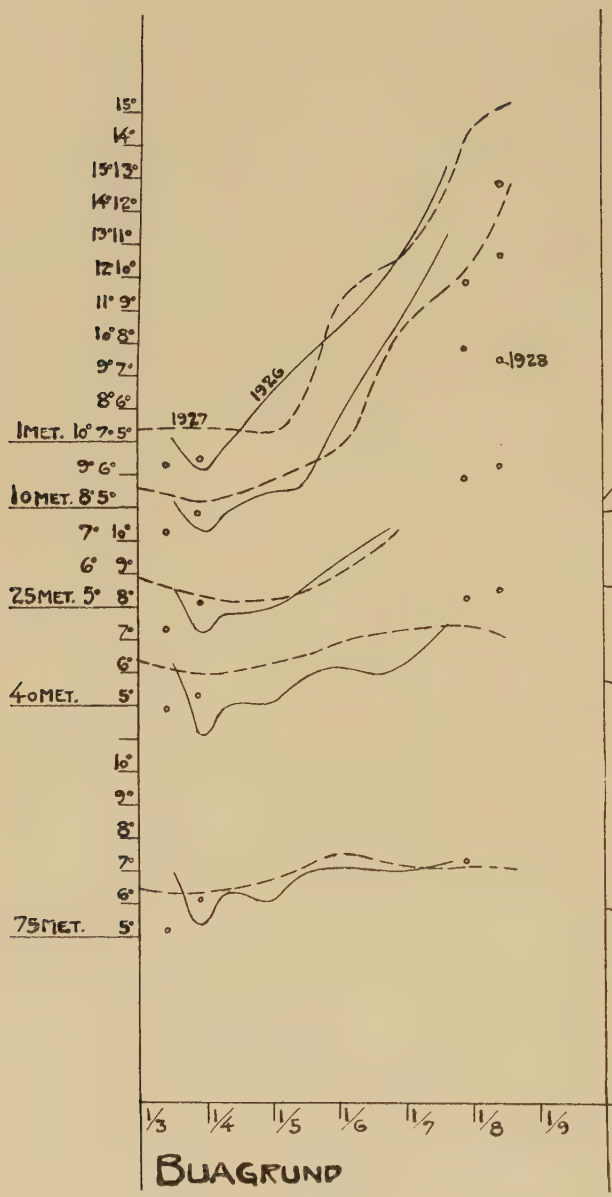

Fig. 38.

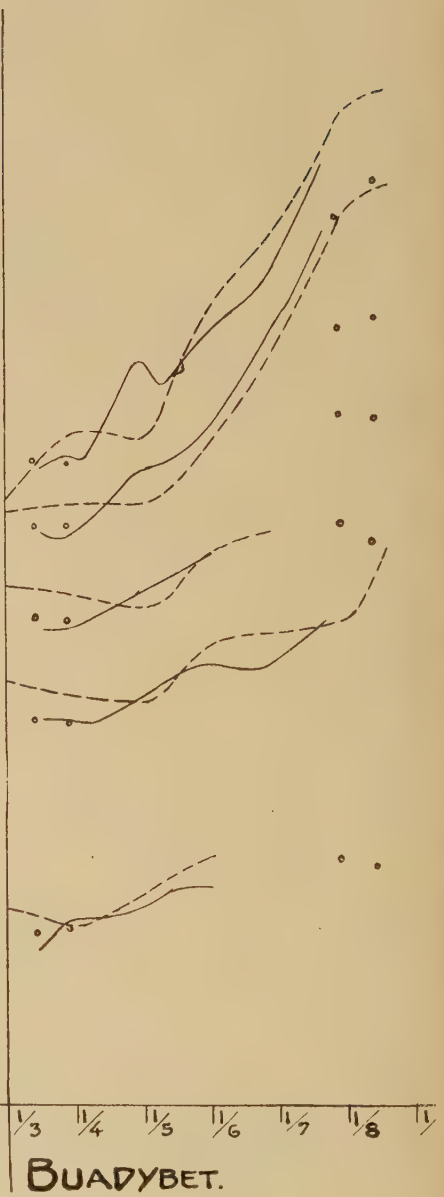

Fig. 39.

The access we have here to more frequently taken sections should enable us to characterize the different years as their variations from each other. It must be noticed, however, that our curves are in part interpolated and therefore fairly unreliable at certain points. They had to be drawn up under the tacit proviso that

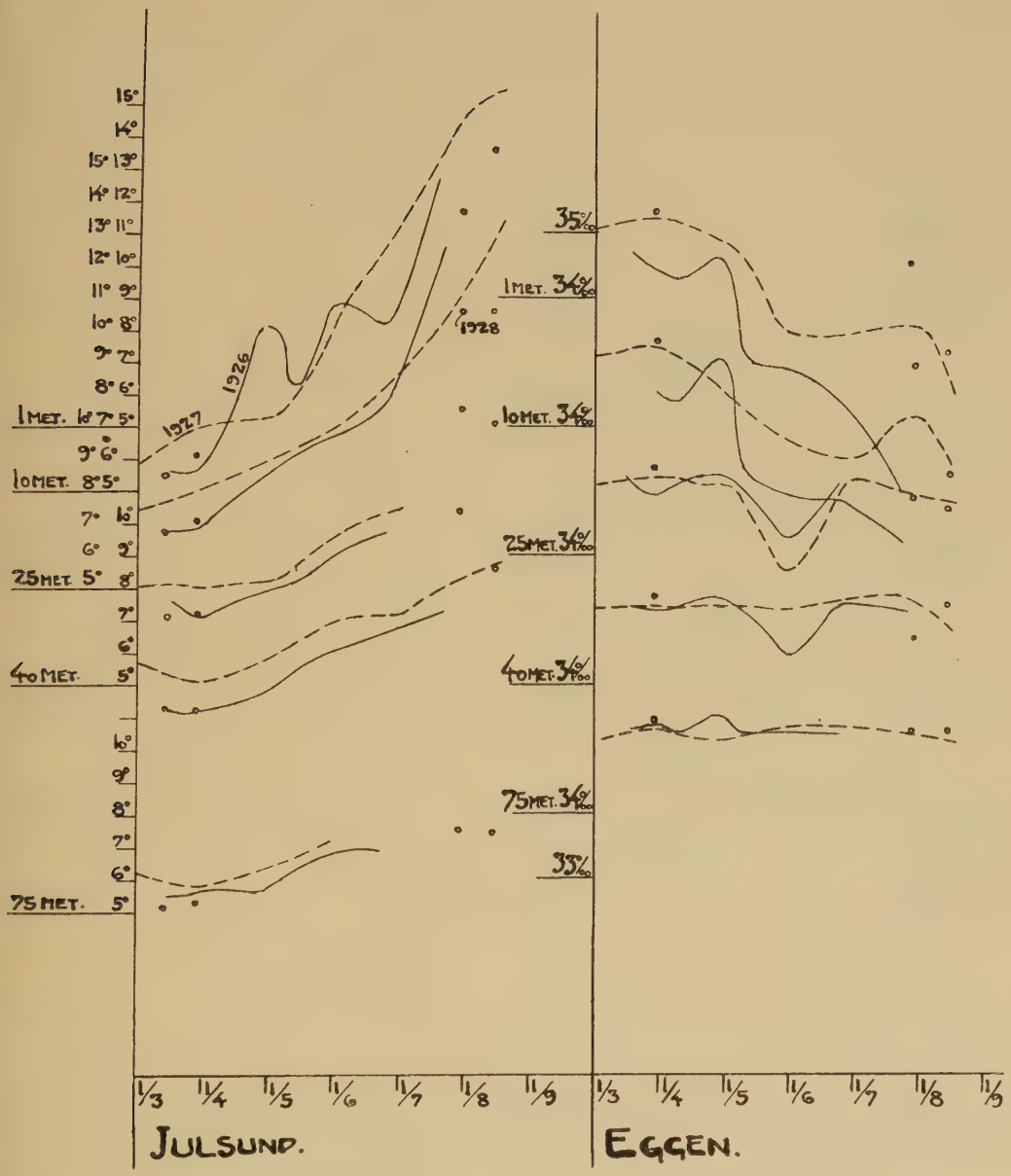

Fig. 40. Fig. 41.

the observed figures represent extreme value for the variations, a proviso not necessarily fulfilled. Even if, consequently, we consider the sections taken at a fortnight's interval as representing an average situation, the average situation thus determined must be expected to be connected with some uncertainty.

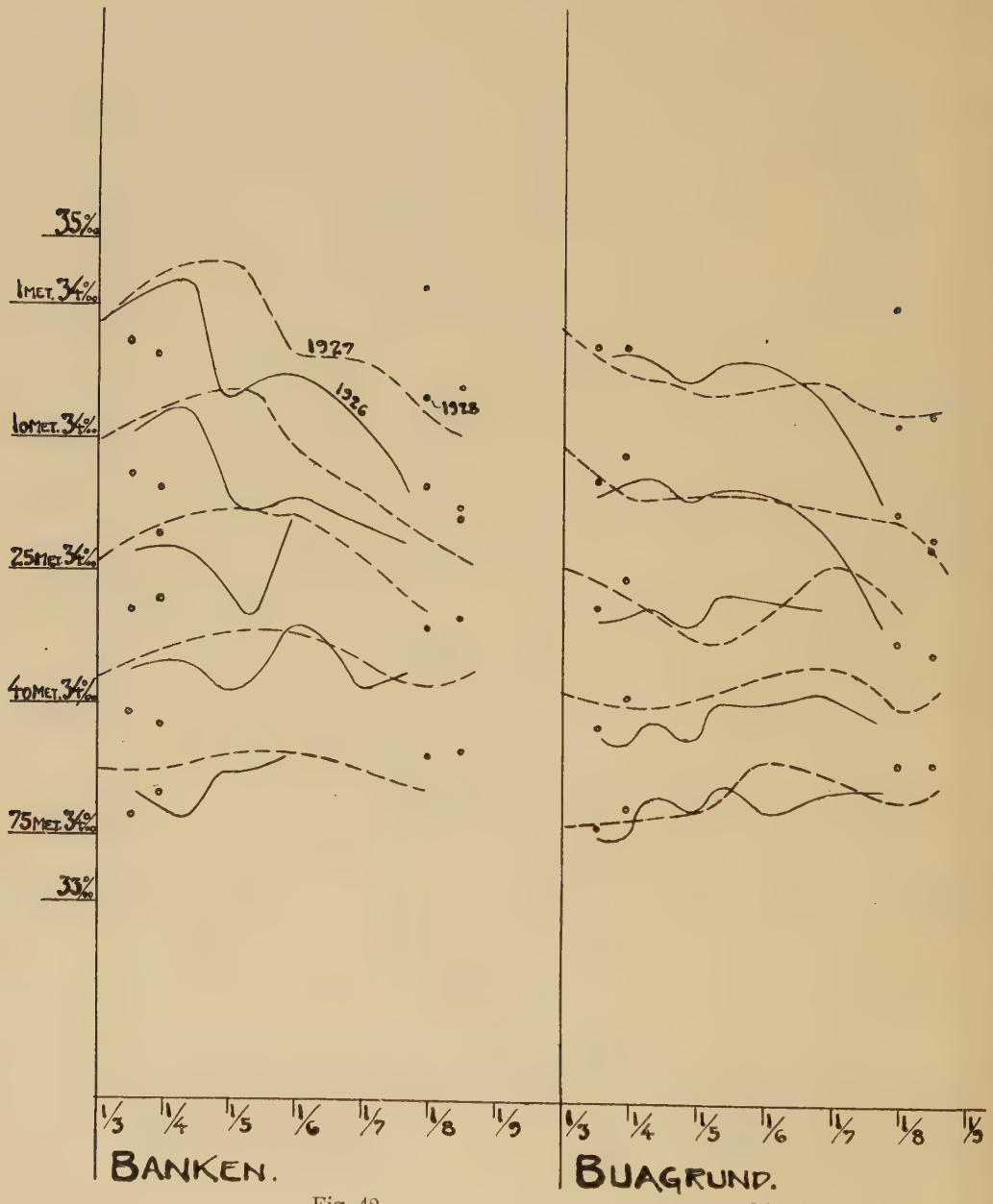

Fig. 42. Fig. 43.

We firstly observe that the curves for 1927 appear to run more regularly than those in 1926. This may, however, be due to the fact that in 1927 sections were taken at greater intervals. The temperature figures in 1927 seem, as a whole,

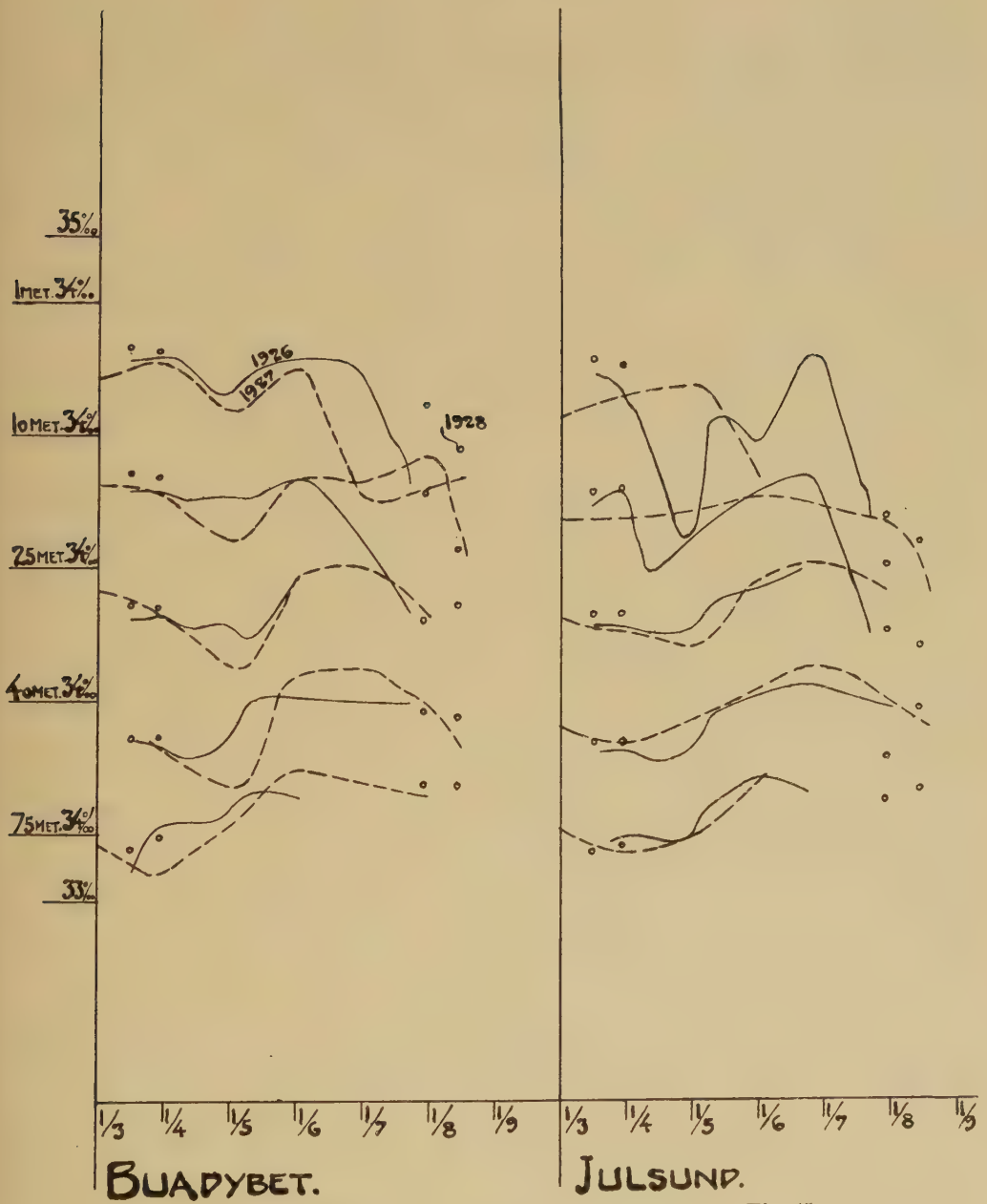

Fig. 44. Fig. 45.

to move along the same average line as in 1926, and we cannot say that one year has been characteristically warmer than the other. However, the heating in 1927 appears at the inner stations to have more deeply penetrated downwards than

in 1926. We have already mentioned one other difference between the temperature distribution of both years. Already in April 1926 (Fig. 16) the warming of the top layers occurred bringing about an intermediate minimum. That intermediate temperature minimum appears in 1927 only in June. In 1926, the mean air temperature figure for April at the lighthouse Ona was 1° higher than the average temperature of surface water, in April 1927 it was 1°.6 lower, in May 0°.6 lower and only in June it turned to be 0°.5 higher.

As to salinity, there is a more highly characterized difference between the years 1926 and 1927. At the outer stations the salinity in the top layers during all the observation period is higher in 1927 than in 1926. At the inner stations, the situation, particularly during the summer, is entirely different (a few surface salinities from the station Julsund could not be included in the diagram because they deviate too much from the others). In the lower layers, the distribution is more similar both years.

The situation in 1928 clearly differs from the situation shown by the years 1926 and 1927. It is certainly worth mentioning that the year 1928 is represented by fewer sections than the preceding ones, but the deviations are so important that they can hardly be due to temporary variations. During the earliest month of observations (March) the temperatures of the year 1928 are about the same as those of the preceding year, at station Banken they are, however, undoubtedly lower. In the observations from August a plain divergence is noticeable, so that the 1928 temperatures in the top layers were lower. At 25 m. and 40 m. levels temperatures were, however, somewhat higher. Regarding salinity the low figures in 1928 at station Banken during March should be noticed. In August the salinity at station Banken is on the contrary higher, and this is as a rule the case at the other stations, especially those situated inside Banken.

This particular position of 1928 compared with the two preceding years also appears in the section outside the continental slope. Temperatures are lower and the vortex motion has nearly disappeared, which probably indicates colder and slowly moving Atlantic water.

It has already been mentioned that it has not been possible for us to discuss here the tidal currents, and despite the fairly large current measuring material we cannot therefore go into the question of the currents existing over Storeggen. Meanwhile, a cursory examination of the material shows that it corresponds, as a whole with the representation of currents given by Helland-Hansen and Nansen (loc. cit. pp. 238 and 259). Both coast water and Atlantic water move mainly in a direction between N. and E. along the coast. The isothermes and isohalines dip down as a rule towards the coast and show how the lighter coast water is pressed towards the coast by the force of its own motion on account of the earth's rotation. Regarding the speed of such motion our current measurements give us a very incomplete picture. They have only been carried out during one period of the year, at the end of the summer, and have been confined to two

stations in order to give series of some length suitable for the analyses of tidal-currents. We find, however, from the already reproduced progressive vector-diagrams, that over Eggen itself the water at a depth of 15 m. moved, on the 9th of August, at a speed of 8.4 cm./sec. to N.E., and on the 15th of August, at a speed of 11.7 cm./sec. northward. At the depth of 135 m. speed and direction were, on the 9th of August, 9.9 cm./sec. towards N.N.E. and on the 15th of August, 13.3 towards N.E. t. N. Further in on the shelf (63°9′ N. 6°1′ E.) the speed on the 31st of July 1927 was, 71 m. deep, 6.6 cm./sec. N.N.W. and 15 m. deep 8.4 cm./sec. towards N. t. E.$^1/_2$E. At the stations studied here, the chief direction of the water motion was found to be N.E., but it is likely that at the other points over the shelf, and may be at other points within our sections, and on account of vortex motions, stations might be found where the water motion would have quite another direction (see Helland-Hansen and Nansen, loc. cit.). The hydrographical sections show that coast water during the spring months is more concentrated along the coast and during the summer months expands further out from the land. This chiefly indicates a greater current-speed of coast water during the spring. It shows further that the water particles that pass at a certain moment outside Stadt during its continued motion, follow different courses, according to the season. Among the particles passing Stadt during the summer time, there are some that follow more westerly courses than those passing the same section in the spring.

In conclusion, we may venture to estimate the time the water masses take to cover certain stretches along the coast. Such estimate, whatever its uncertainty may be, is no doubt of importance for the discussion of some of the biological problems. The particles that at a given period pass a section, for inst., outside Lindesnäs, need quite different times in order to reach a section over Storeggen. The problem should therefore be formulated more exactly by asking the time it takes for, say, 50 % of water from Lindesnäs to reach the section over Storeggen. The insufficient material that is at our disposal to answer this question, dispenses us from examining any further how the question should be formulated. We found that the current-speed over the bank at Storeggen is of the magnitude of 10 cm./sec. or 5 miles per 24 hours. During the spring-months, the speed is most certainly greater, and further towards the south, outside the coast, south of Stadt, where coast water forms a fairly narrow current, the speed must surely be greater (see Helland-Hansen and Nansen, loc. cit.). But according to what we already mentioned the problem itself is, on account of the whirling motions, so vague that we need not pay any attention to it, and shall therefore take the average velocity of the water motion at the rate of 5 miles per 24 hours. We find then that the water particles that at a given time pass through the Storeggen section, passed Cape Stadt about 3 weeks earlier and Lindesnäs about 10 weeks earlier. Once more, we must emphasize that these estimations are, for the most part, guesses that would be of little value viewed in the light of a criticism based on a more accurate knowledge of the vortex motions.

Table I. Temperature, salinity, σ_t, contents of oxygen, degree of oxygen saturation and hydrogen ionconcentration.

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 1. 1925. V 26 5 p.m. Julsund						
0	9,5	31,78	24,54	...	...	...
10	6,9	33,89	26,58	...	...	...
20	7	34,16	81	...	...	...
50	6	38	27,01	...	...	...
100	9	69	20	...	...	...
200	7,2	90	34	...	...	...
St. 3. 1925. V 27 3 p.m. 63°16′N 6°37′E						
10	8,2	33,57	26,14	...	...	...
50	6,5	34,25	91	...	...	...
100	7,5	35,05	27,40	...	...	...
150	6	14	46	...	...	...
St. 4. 1925. V 27 6^{30} p.m. 63°23′ N 6°8′ E						
10	7,90	33,46	25,93	...	...	...
50	75	34,94	27,29	...	...	...
100	80	35,21	49	...	...	...
200	60	25	54	...	...	...
St. 5. 1925 V 28 4 a.m. 63°19′ N 5°19′ E						
10	8,5	32,84	25,42	...	...	...
50	7,8	35,12	27,41	...	...	...
100	7	25	53	...	...	...
200	4	23	57	...	...	...
St. 9. 1925. VII 22 10 am. 63°32′5 N 5°39′5 E						
0	13,43	34,22	25,71	...	...	...
50	9,53	35,26	27,26	...	...	...
100	28	37	38	...	...	...
200	8,83	37	47	...	...	...
400	7,78	28	55	...	...	...
St. 10. 1925. VII 22 4^{30} p.m. 63°21′5 N 5°33′E						
0	13,78	33,95	25,45	...	...	...
50	8,83	35,05	27,20	...	...	...
100	33	21	41	...	...	...
200	7,83	17	46	...	...	...
St. 13. 1925. VII 23 4 a.m. 62°57′ N 6°43′ E						
0	15,37	31,76	23,42	...	...	...
50	8,08	34,56	26,94	...	...	...
100	7,83	92	27,76	...	...	...
200	68	35,12	91	...	...	...
St. 14. 1925. VII 24 5^{50} a.m. 63°37′ N 7°6′ E						
0	14,72	31,73	23,53	...	...	...
50	12,63	34,11	25,79	...	...	...
100	8,23	35,12	27,36	...	...	...
200	7,78	21	50	...	...	...
St. 21. 1925. VIII 11 11^{30} a.m. 63°15′ N 5°53′ E						
0	15,12	32,48	24,03	...	...	...
50	7,58	34,90	27,29	...	...	...
100	63	35,17	34	...	...	...
140	73	17	33	...	...	...
St. 22. 1925. VIII 11 4^{15} p.m. 63°26′5 N 5°14′ E						
0	...	33,19	...	...	...	...
50	8,33	34,90	27,17	...	...	...
100	7,63	35,17	34	...	...	...
200	63	19	35	...	...	...
St. 25. 1925. VIII 17 4 a.m. 174′ NW Björnsund						
0	11,63	35 07	26,73	...	...	...
50	7,53	19	27,51	...	...	...
100	6,98	14	55	...	...	...
200	5,24	34,97	65	...	...	...
St. 26. 1925. VIII 17 9 a.m. 144′ NW Björnsund						
0	12,63	35,08	26,54	...	...	...
50	8,83	17	27,31	...	...	...
100	48	28	44	...	...	...
200	6,28	23	71	...	...	...
St. 27. 1925. VIII 17 1^{50} p.m. 114′ NW Björnsund						
0	12,5	34,96	26,48	...	...	...
50	9,1	35,26	27,33	...	...	...
100	8,7	30	42	...	...	...
200	0	28	51	...	...	...
St. 28. 1925. VIII 17 7^{30} p.m. 84′ NW Björnsund						
0	13,3	34,51	25,81	...	...	...
50	9,1	35,19	27,27	...	...	...
100	8,2	25	45	...	...	...
200	7,0	17	58	...	...	...
300	5,3	12	75	...	...	...
St. 29. 1925. VIII 18 1^{30} a.m. 52′ NW Björnsund						
0	12,33	33,64	25,48	...	...	...
50	9,73	35,25	27,21	...	...	...
100	33	32	32	...	...	...
200	8,53	23	39	...	...	...
St. 35. 1926. III 16 5 a.m. 48′ NW Björnsund (Eggen)						
1	6,71	34,72	27,26	...	...	...
10	...	78	...	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
25	7,70	35,16	27,46	...	...	...
40	81	19	48	...	...	...
75	8,21	30	50	...	...	...
100	11	35	55	...	...	...
250	6,94	23	63	...	...	...
400	91	19	60	...	...	...
500	71	12	58	...	...	...

St. 36. 1926. III 16 11 a.m. 32′ NW Björnsund (Banken)

1	5,21	34,00	26,88	...	...	...
10	31	05	90	...	...	...
25	70	29	27,05	...	...	...
40	81	42	13	...	...	...
75	6,41	70	29	...	...	...
100	7,01	97	42	...	...	...

St. 37. 1926. III 16 2^{30} p.m. 17′ NW Björnsund (Buagrund)

1	5,2	33,13	26,32	...	...	...
10	3	13	32	...	...	...
25	7	26	39	...	...	...
40	6,4	60	60	...	...	...
75	7,0	96	80	...	...	...

St. 38. 1926. III 16 5^{15} p.m. 5′ NNW Björnsund (Buadypet)

1	4,0	33,13	26,32	...	...	...
10	1	17	35	...	...	...
25	1	24	40	...	...	...
40	2	35	48	...	...	...
75	5	46	53	...	...	...
100	...	...	...	...	...	...
150	6,4	34,54	27,15	...	...	...

St. 42. 1926. III 18 11 a m. Julsund

1	3,7	32,94	26,20	...	...	...
10	8	95	21	...	...	...
25	4,1	33,17	34	...	...	...
40	2	26	40	...	...	...
75	5,5	73	63	...	...	...
100	6,0	34,11	89	...	...	...
200	2	34	27,04	...	...	...

St. 43. 1926. III 26 2^{30} p.m. Julsund

1	3,72	32,66	25,98	8,30	112,5	...
10	92	33,12	26,33	7,23	98,8	...
25	4,04	19	37	07	96,9	...
40	35	26	38	6,70	92,7	...
75	5,56	98	82	54	93,6	...
100	89	34,23	98	42	92,6	...
150	6,23	56	27,19	28	92,4	...

St. 44. 1926. III 26 5 p.m. 5′ NNW Björnsund

1	4,43	33,15	26,30	7,07	98,0	...
10	05	19	37	38	100,9	...
25	20	26	40	24	100,7	...
40	4,46	33,35	26,45	6,91	97,3	...
75	5,53	34,14	96	57	93,9	...
100	6,07	40	27,09	39	92,6	...
150	33	58	20	33	92,5	...

St. 45. 1926. III 26 8 p.m. 17′ NW Björnsund

1	4,06	33,21	26,37	7,29	99,7	...
10	09	26	41	22	99,0	...
25	05	30	44	12	97,7	...
40	08	33	47	04	96,7	...
75	5,43	98	84	6,43	92,8	...

St. 46. 1926. III 27 3^{20} a.m. 50′5 NW Björnsund

1	6,19	34,43	27,10	7,25	105,4	...
10	27	51	15	17	104,8	...
25	7,00	97	29	6,37	94,8	...
40	26	35,12	39	30	94,5	...
75	8,11	34	54	27	95,9	...
100	11	55	71	...	...	...
250	7,01	16	56	6,20	92,3	...
400	6,73	12	58	34	93,8	...
500	5,21	34,99	67	43	89,9	...

St. 47. 1926. IV 9 6 a.m. 5′ NNW Björnsund

1	4,46	33,08	26,23	7,94	110,1	...
10	44	06	22	93	110,0	...
25	41	12	27	91	109,7	...
40	38	12	27	45	103,4	...
75	5,56	34,16	26,96	6,56	93,6	...
100	76	31	27,05	31	89,6	...
150	6,48	76	31	29	92,4	...

St. 48. 1926. IV 9 9^{30} a.m. 17′ NW Björnsund

1	4,66	33,40	26,49	7,61	106,0	...
10	62	39	48	70	107,1	...
25	65	49	56	46	106,3	...
40	91	75	72	6,82	95,8	...
75	6,32	34,65	27,25	42	94,3	...

St. 49. 1926. IV 9 1^{30} p.m. 32′ NW Björnsund

1	6,04	34,38	27,09	7,06	102,3	...
10	12	43	11	6,97	101,4	...
25	10	54	20	89	100,2	...
40	13	63	26	80	99,3	...
75	7,43	35,23	56	48	97,5	...
100	66	19	49	47	97,7	...

St. 50. 1926. IV 9 6 p.m. 50′ NW Björnsund

1	7,51	34,33	26,84	7,13	106,8	...
10	63	34	85	6,72	100,8	...
25	40	35,16	27,50	91	103,8	...
40	61	23	54	56	98,9	...
75	41	25	57	53	98,1	...
100	42	26	59	51	97,8	...
250	6,89	21	62	48	96,3	...
400	00	21	74	47	94,3	...
500	3,84	34,99	82	74	93,0	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 51. 1926. IV 10 11 a.m. Julsund						
1	4,66	31,94	25,31	8,14	112,3	...
10	52	32,83	26,04	22	114,2	...
25	40	33,03	20	7,87	108,8	...
40	41	10	25	71	106,8	...
75	5,76	93	74	6,30	90,4	...
100	6,06	34,14	89	39	92,4	...
150	35	63	27,23	15	90,1	...
St. 52. 1926. IV 28 2^{30} p.m. Julsund						
1	8,01	30,41	23,70	7,40	109,1	...
10	5,52	32,47	25,64	35	104,0	...
25	00	33,06	26,16	13	100,0	...
40	4,93	22	31	6,88	96,4	...
75	5,76	89	72	35	91,1	...
100	6,31	34,40	27,06	5,94	86,7	...
150	53	72	28	99	88,1	...
St. 53. 1926. IV 28 6 p.m. 5′ NNW Björnsund						
1	7,21	32,66	25,61	7,12	104,7	...
10	5,92	33,10	26,08	13	102,2	...
25	31	17	21	04	99,5	...
40	06	31	35	6,84	96,2	...
75	92	34,25	99	31	91,2	...
100	6,31	63	27,24	5,93	86,7	...
150	93	88	36	6,12	93,1	...
St. 54. 1926. IV 28 9 p.m. 15′5 NW Björnsund						
1	6,39	32,84	25,82	7,11	102,8	...
10	5,42	33,03	26,09	10	100,6	...
25	4,95	13	22	6,84	95,9	...
40	5,01	42	45	86	96,5	...
75	6,01	34,33	27,04	33	91,8	...
St. 55. 1926. IV 29 6 a.m. 32′ NW Björnsund						
1	7,32	32,61	25,52	7,02	103,4	...
10	5,17	33,28	26,32	6,81	96,1	...
25	50	82	41	54	95,4	...
40	6,01	34,29	27,01	52	94,3	...
75	7,11	96	38	23	93,0	...
100	57	35,14	47	29	94,9	...
St. 56. 1926. IV 29 10 a.m. 44′ NW Björnsund						
1	8,01	34,13	26,61	7,31	110,4	...
10	27	87	27,15	13	109,0	...
25	35	35,23	41	6,46	99,1	...
40	61	35	48	67	103,0	...
75	66	37	49	55	101,4	...
100	55	34	48	06	93,4	...
175	7,92	23	48	22	96,87	...
St. 57. 1926. IV 29 1 p.m. 50′ NW Björnsund						
1	8,96	34,69	26,91	7,21	111,8	...
10	52	35,03	27,24	02	107,8	...
25	50	26	43	6,60	101,5	...
40	66	37	49	23	96,5	...
75	8,67	35,52	27,60	6,24	96,9	...
100	46	55	65	32	97,5	...
350	7,13	16	54	45	96,4	...
400	6,93	12	54	40	95,1	...
500	29	07	59	5,55	81,4	...
St. 60. 1926. V 12 7^{30} a.m. Julsund						
1	6,36	32,27	25,37	7,39	106,3	...
10	27	72	74	39	106,4	...
25	5,30	33,44	26,42	6,82	96,6	...
40	59	78	67	48	92,6	...
75	6,38	34,45	27,09	28	92,0	...
150	7,02	76	25	18	91,8	...
St. 61. 1926. V 12 10^{30} a.m. 5′ NNW Björnsund						
1	6,69	32,95	25,87	7,04	102,4	...
10	19	33,08	26,04	14	103,0	...
25	5,67	91	76	6,54	93,6	...
40	74	34,05	86	33	90,8	...
75	6,51	63	27,21	27	92,2	...
100	65	79	33	19	91,4	...
150	7,27	97	38	19	92,7	...
St. 62. 1926. V 12 1^{50} p.m. 17′5 NW Björnsund						
1	7,27	33,08	25,89	7,38	109,0	...
10	5,47	33	26,31	12	101,2	...
25	40	64	57	6,57	93,5	...
40	72	34,00	82	43	92,3	...
75	6,93	76	27,26	16	91,4	...
St. 63. 1926. V 12 5 p.m. 31′5 NW Björnsund						
1	7,27	32,81	25,67	7,28	107,4	...
10	6,44	88	84	55	111,9	...
25	5,70	33,22	26,22	07	100,7	...
40	87	34,29	27,03	6,33	91,4	...
75	7,41	92	31	29	94,5	...
100	82	35,07	38	30	95,6	...
St. 64. 1926. V 12 8 p.m. 45′ NW Björnsund						
1	7,34	33,01	25,81	7,19	106,4	...
10	6,93	33	26,13	24	106,3	...
25	8,01	35,01	27,31	6,29	95,7	...
40	32	10	33	30	96,5	...
75	63	25	39	35	98,1	...
100	49	34	49	68	102,8	...
200	7,48	17	51	28	94,6	...
300	21	12	50	31	94,5	...
St. 66. 1926. VI 1 8 p.m. Julsund						
1	8,93	31,92	24,74	8,14	123,3	...
10	6,88	33,17	26,01	7,88	115,3	...
25	15	62	47	10	102,8	...
40	11	34,02	79	6,61	95,9	...
75	83	85	27,36	11	90,4	...
100	7,00	35,03	46	05	90,2	...
150	32	17	54	18	92,8	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 67. 1926. IV 2 9^{20} a.m. 5′ NNW Björnsund						
1	8,13	33,10	25,78	6,30	94,9	...
10	7,09	37	26,14	97	102,8	...
25	6,40	87	64	74	98,3	...
40	19	34,02	78	55	95,1	...
75	43	54	27,16	01	88,1	...
100	62	63	20	05	89,3	...
150	7,15	97	40	08	90,9	...
St. 68. 1926. IV 2 12^{30} p.m. 17′ NW Björnsund						
1	8,33	33,01	25,68	6,98	105,4	...
10	7,75	17	89	7,07	105,5	...
25	6,23	53	26,38	6,91	99,9	...
40	19	34,00	76	17	89,4	...
75	7,07	34	90	16	91,4	...
St. 69. 1926. IV 2 3^{30} p.m. 32′ NW Björnsund						
1	8,93	32,99	25,58	6,76	103,4	...
10	44	33,08	72	86	104,0	...
25	7,91	34,92	27,24	67	101,2	...
40	95	35,12	40	25	95,4	...
75	8,28	25	44	33	97,1	...
100	7,97	25	49	24	95,1	...
St. 70. 1926. IV 2 5^{45} p.m. 46′ NW Björnsund						
1	8,18	32,86	25,58	6,91	104,0	...
10	10	94	65	93	104,2	...
25	5,99	34,25	26,98	57	95,1	...
40	6,26	45	27,11	30	92,0	...
75	8,46	35,25	41	...	...	...
100	52	32	46	07	93,5	...
200	16	28	49	23	95,3	...
300	7,87	19	46	26	95,2	...
St. 71. 1926. IV 10 7^{05} a.m. Log 45′ course NW t. W Björnsund						
0	11,27	32,52	24,82	...	...	...
40	9,77	35,21	27,18	...	...	...
100	8,85	32	41	...	...	...
200	7,81	19	47	...	...	...
St. 72. 1926. IV 10 11^{15} a.m. Log 75′ course NW t. W½W from stat. 71						
0	11,81	34,92	26,58	...	...	...
40	8,46	35,23	27,40	...	...	...
100	7,85	23	50	...	...	...
200	12	17	56	...	...	...
St. 73. 1926. VI 10 3^{05} p.m. Log 105′ course NW t. W½W from stat. 71						
0	12,67	32,86	24,83	...	...	...
40	9,00	35,28	27,35	...	...	...
100	8,86	30	39	...	...	...
200	19	28	48	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 74. 1926. VI 10 7^{10} p.m. Log 135′ course NW t. W½W from stat. 71						
0	11,87	34,13	25,94	...	...	...
40	8,92	35,32	27,39	...	...	...
100	07	25	47	...	...	...
200	7,05	21	50	...	...	...
St. 75. 1926. VI 10 10^{45} p.m. Log 160′ course NW t. W½W from stat. 71						
0	11,20	35,25	26,94	...	...	...
40	8,43	26	27,43	...	...	...
100	7,32	16	52	...	...	...
200	6,39	10	61	...	...	...
St. 76. 1926. VI 11 7^{05} a.m. Log 195′ course NW t. W½W from stat. 71						
0	9,93	35,16	27,15	...	...	...
40	7,46	17	51	...	...	...
100	5,08	34,92	62	...	...	...
200	2,02	85	87	...	...	...
St. 77. 1926. VI 11 11^{15} a.m. Log 217′ course NW t. W½W from stat. 71						
0	10,29	34,97	26,91	...	...	...
40	6,79	35,01	27,49	...	...	...
100	4,30	34,92	71	...	...	...
200	1,89	85	88	...	...	...
St. 78. 1926. VI 26 3 p.m. Julsund						
1	8,31	33,24	25,87	7,49	113,3	...
10	7,62	40	26,09	60	113,4	...
25	6,77	34,07	74	6,26	92,1	...
40	73	22	86	5,98	87,9	...
75	90	56	27,10	83	88,5	...
100	92	63	16	...	...	...
150	7,20	83	28	...	...	...
St. 79. 1926. VI 24 8^{45} p.m. 5′ NNW Björnsund						
1	9,39	33,08	25,58	...	...	...
40	5,93	98	26,78	...	...	...
100	6,96	34,74	27,24	...	...	...
150	7,37	92	32	...	...	...
St. 80. 1926. VI 24 11^{45} p.m. 17′ NW Björnsund						
1	10,13	32,61	25,09	6,64	104,0	...
10	13	70	15	61	103,6	...
25	7,31	33,49	26,21	7,24	107,3	...
40	5,93	34,11	88	6,33	91,4	...
75	6,86	63	27,17	14	91,0	...
St. 81. 1926. VI 25 3^{30} a.m. 32′ NW Björnsund						
1	10,93	32,45	24,82	...	...	...
40	6,08	34,25	26,97	...	...	...
100	7,76	35,08	27,39	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 82. 1926. VI 25 6^{30} a.m. 45′ NW Björnsund						
1	10,93	32,43	24,81	6,49	103,1	...
10	99	83	25,11	44	102,9	...
25	9,51	35,17	27,20	45	101,4	...
40	40	28	28	23	97,8	...
75	10	25	31	18	96,4	...
150	8,77	23	35	...	...	...
300	76	21	35	...	...	...
St. 85. 1926. VII 20 8 a.m. Julsund						
1	13,29	30,73	23,06	...	...	...
10	12,96	97	31	...	...	...
40	7,33	34,00	26,61	...	...	...
100	6,93	63	27,16	...	...	...
150	7,32	83	27	...	...	...
St. 86. 1926. VII 20 1 p.m. 5′ NNW Björnsund						
1	13,22	31,27	23,48	...	...	...
10	07	35	57	...	...	...
40	7,41	34,00	26,59	...	...	...
100	31	81	27,26	...	...	...
150	81	35,01	34	...	...	...
St. 87. 1926. VII 20 4^{15} p.m. 17′ NW Björnsund						
1	13,41	30,82	23,10	...	...	...
10	29	31,02	28	...	...	...
40	7,41	33,73	26,38	...	...	...
75	39	34,74	27,18	...	...	...
St. 88. 1926. VII 20 7^{30} p.m. 32′ NW Björnsund						
1	12,97	31,13	23,42	...	...	...
10	70	32,32	24,40	...	...	...
40	6,69	34,49	27,08	...	...	...
100	8,16	35,17	30	...	...	...
St. 89. 1926. VII 20 10^{30} p.m. 47′ NW Björnsund						
1	13,42	31,02	23,26	...	...	...
10	12,84	32,18	24,26	...	...	...
40	10,26	35,19	27,08	...	...	...
100	9,08	32	37	...	...	...
200	8,38	23	41	...	...	...
300	7,80	19	48	...	...	...
St. 101. 1927. III 1 8 a.m. 5′ NNW Björnsund (Buadypet)						
1	2,99	32,86	26,20	7,08	94,3	...
10	4,97	33,26	32	10	99,9	...
25	5,57	62	54	6,85	97,6	...
40	67	...	...	86	...	...
75	93	33,86	26,68	75	97,3	...
150	46	34,25	92	58	96,2	...
St. 102. 1927. III 1 11 a.m. 17′ NW Björnsund (Buagrund)						
1	5,26	33,58	26,55	7,05	99,9	...
10	61	82	70	6,87	98,3	...
25	5,96	34,04	26,81	6,76	97,5	...
40	6,30	11	83	57	95,6	...
75	41	18	88	61	96,5	...
St. 103. 1927. III 1 1^{45} p.m. 32′ NW Björnsund (Banken)						
1	5,59	33,78	26,67	6,63	94,7	...
10	92	95	75	83	98,4	...
25	6,14	34,07	82	66	96,7	...
40	66	31	94	47	95,2	...
75	7,53	97	27,35	41	96,4	...
120	63	35,03	37	17	93,1	...
St. 104. 1927. III 1 5^{15} p.m. 48′ NW Björnsund (Eggen)						
1	6,99	35,10	27,52	6,66	99,3	...
10	99	12	53	57	97,9	...
25	96	15	56	65	98,9	...
40	93	14	56	40	95,2	...
75	92	10	55	59	97,9	...
150	76	08	53	59	97,8	...
St. 105. 1927. III 2 5^{30} a.m. Julsund						
1	3,90	32,30	25,67	7,23	98,2	...
10	4,49	75	98	27	100,6	...
25	5,13	33,28	26,33	6,91	97,5	...
40	73	66	54	82	97,7	...
75	6,30	34,07	80	64	96,6	...
150	81	29	90	42	94,5	...
St. 106. 1927. III 22 9 a.m. Julsund						
1	4,82	32,74	25,93	7,73	107,6	8,19
10	91	97	26,10	59	106,1	25
25	98	33,03	14	55	105,9	20
40	5,09	04	15	49	105,2	16
75	6,78	96	65	6,25	91,9	07
175	96	34,34	93	07	89,9	04
St. 107. 1927. III 22 2^{45} p.m. 62°40′,5 N, 7°6′ E						
1	5,26	32,77	25,90	7,99	112,6	8,18
10	26	86	97	81	110,2	24
25	24	97	26,06	68	109,3	16
40	54	33,06	10	16	101,5	15
75	7,64	91	49	5,89	88,2	14
150	26	34,40	93	92	88,2	13
250	21	67	27,13	47	81,6	05
400	08	76	24	42	80,7	05
St. 108. 1927. III 22 6^{30} p.m. 62°34′ N, 7°27′ E						
1	5,14	31,27	24,73	7,83	111,4	8,22
10	4,92	32,45	25,69	8,11	112,8	...
25	5,06	75	91	7,81	109,4	...
40	6,93	33,35	26,15	6,17	90,6	...
75	7,82	34,16	66	5,73	86,3	8.13
150	49	49	96	...	...	07

m	$t°$	S ‰	σ_t	O_2	M %	p_H
250	7,06	34,70	27,20	5,41	80,5	8,05
350	03	81	30	61	83,5	02

St. 109. 1927. III 28 7 a.m. 51′ NW Björnsund (Eggen)

1	8,02	35,21	27,46	6,60	100,6	8,10
10	09	21	45	49	99,1	13
25	21	23	44	46	98,9	18
40	38	25	42	41	98,5	15
75	38	30	47	43	98,9	18
150	12	26	48	38	97,5	...
250	7,47	21	64	60	99,4	...
400	6,80	12	57	61	98,1	8,09

St. 110. 1927. III 28 10 a.m. 44′ NW Björnsund

1	6,70	34,45	27,05	7,61	112,0	8,28
10	71	49	08	49	110,5	25
25	7,43	85	26	6,62	99,2	12
40	77	99	32	39	96,7	05
75	8,08	35,03	31	36	96,9	01
150	01	25	48	39	97,4	13
300	7,90	21	47	29	95,6	10

St. 111. 1927. III 28 2 p.m. 32′ NW Björnsund (Banken)

1	6,64	34,42	27,03	7,58	111,5	8,25
10	52	47	09	48	109,8	24
25	94	67	19	6,57	97,5	01
40	99	74	24	79	100,9	06
75	7,57	99	35	25	94,2	09
120	64	35,12	44	32	95,5	06

St. 112. 1927. III 28 5 p.m. 17′ NW Björnsund (Buagrund)

1	5,36	32,90	25,99	7,70	109,1	8,26
10	13	33,08	26,16	69	108,1	19
25	38	58	51	21	102,8	13
40	93	91	72	6,88	99,1	10
60	6,37	34,23	92	70	97,8	13

St. 113. 1927. III 28 7^{30} p.m. 5′ NNW Björnsund (Buadypet)

1	5,13	33,08	26,16	7,84	110,5	8,25
10	07	10	18	52	105,6	23
25	19	33	35	29	103,0	19
40	22	37	37	29	103,1	15
75	29	44	40	29	103,2	18
150	6,11	34,60	27,13	6,56	97,2	16

St. 114. 1927. III 29 10 a.m. Julsund

1	5,08	32,68	25,85	7,63	106,9	8,21
10	07	84	98	55	105,9	16
25	08	33,08	26,17	41	104,2	18
40	18	26	30	37	104,0	19
75	85	75	61	6,75	97,0	13
175	6,84	34,58	27,13	29	93,1	12

m	$t°$	S ‰	σ_t	O_2	M %	p_H

St. 115. 1927. V 3 9^{30} a.m. 5′ NNW Björnsund (Buadypet)

1	4,98	32,39	25,64	7,25	101,1	8,24
10	97	41	65	33	102,2	22
25	95	41	66	35	102,3	21
40	5,18	66	82	00	98,3	20
75	6,46	34,16	26,85	6,49	94,9	16
100	84	...	...	...	...	15
150	7,14	34,70	27,19	6,31	94,0	13

St. 116. 1927. V 3 1 p.m. 17′ NW Björnsund (Buagrund)

1	5,15	32,56	25,74	7,37	103,4	8,22
25	34	90	99	34	103,9	21
75	6,61	34,42	27,09	6,49	95,4	18

St. 117. 1927. V 3 4 p.m. 32′ NW Björnsund (Banken)

1	7,03	34,69	27,19	6,54	97,2	8,18
10	07	72	21	60	98,2	17
25	55	35,01	38	35	95,6	15
40	65	08	41	34	95,8	13
75	98	26	50	5,69	86,7	14
100	62	23	53	6,22	94,0	15

St. 118. 1927. V 3 7 p.m. 47′ NW Björnsund (Eggen)

1	7,07	34,81	27,29	6,05	92,3	8,18
25	64	35,10	43	5,78	87,2	17
75	43	14	49	6,53	98,2	16
125	34	21	56	68	100,3?	15
200	33	26	60	58	98,8	15

St. 119. 1927. V 4 4 a.m. Julsund

1	5,27	32,74	25,87	7,39	104,1	8,23
25	26	83	95	46	105,2	24
75	6,43	33,98	26,71	6,41	93,6	19
125	...	...	...	...	...	...
175	6,75	34,29	26,91	6,32	93,1	8,18

St. 121. 1927. VI 1 9 a.m. Julsund

1	8,51	31,31	24,33	7,41	111,1	8,23
10	6,93	33,12	25,97	32	107,2	18
25	81	82	26,55	6,61	97,1	14
40	7,09	34,20	80	30	93,5	09
75	33	85	27,27	49	97,1	12
100	44	96	34	42	96,4	11
175	53	35,01	38	36	95,8	11

St. 122. 1927. VI 1 1 p.m. 5′ NNW Björnsund (Buadypet)

1	8,92	32,97	25,56	7,41	113,3	8,18
10	6,76	33,39	26,22	41	108,3	...
25	54	86	60	6,66	97,2	...
40	80	34,33	94	45	95,2	8,08

m	$t°$	S ‰	σ_t	O_2	M %	p_H
75	7,36	34,92	27,32	6,26	93,9	8,09
150	60	35,14	47	18	93,2	11

St. 123. 1927. VI 1 4^{15} p.m. 17′ NW Björnsund (Buagrund)

1	9,08	32,74	25,36	7,15	109,5	8,19
10	6,74	33,03	94	72	112,6	24
25	5,92	37	26,30	6,95	99,9	19
40	6,82	34,47	27,04	41	94,7	09
75	7,56	35,08	42	04	91,1	09

St. 124. 1927. VI 1 7^{30} p.m. 32′ NW Björnsund (Banken)

1	9,23	33,28	25,75	7,00	108,0	8,23
10	7,49	82	26,45	84	116,9	26
25	43	34,83	27,25	6,32	94,9	19
40	68	35,10	43	41	97,0	18
75	79	21	49	26	95,0	16
100	78	23	50	33	96,1	15

St. 125. 1927. VI 1 11 p.m. 48′ NW Björnsund (Eggen)

1	8,99	33,49	25,96	7,17	110,1	8,27
10	36	78	26,29	88	119,8	30
25	7,43	34,78	27,21	6:64	99,7	22
40	89	35,14	43	36	96,7	19
75	8,11	32	51	39	97,6	...
150	7,92	26	52	40	97,4	...
300	14	23	60	41	95,8	...

St. 126. 1927. VI 21 8^{30} a.m. Julsund

1	10,44	30,17	23,14	6,83	105,7	8,27
10	9,01	32,63	25,29	7,12	108,8	27
25	7,73	33,84	26,43	6,42	96,7	18
40	36	34,34	88	5,98	89,4	13
100	29	78	27,23	97	90,0	13
175	43	35,01	39	6,01	90,4	12

St. 127. 1927 VI 21 2^{30} p.m. 62°40′,5 N, 7°6′ E

1	10,61	29,22	22,37	6,71	103,9	8,24
10	8,29	32,84	25,56	7,27	109,6	26
25	7,52	33,46	26,15	17	106,7	24
40	33	34,34	88	5,59	83,4	08
75	19	61	27,11	55	82,8	08
150	19	72	19	78	88,4	07
250	30	78	23	...	...	10
400	36	97	37	5,98	89,7	12

St. 128. 1927. VI 21 5^{45} p.m. 62°34′ N, 7°27′ E

1	11,46	20,53	15,53	7,02	102,3	8,28
10	8,68	31,89	24,76	33	110,6	26
25	7,13	33,57	26,29	6,92	102,2	20
40	59	34,38	88	5,54	83,2	08
75	23	58	27,08	35	79,9	08
150	13	74	22	...	...	08
250	7,34	34,85	27,27	...	...	8,11
350	36	85	27	...	...	11

St. 129. 1927. VI 29 8^{30} a.m. Julsund

1	11,26	27,83	21,18	6,99	106,6	8,23
10	8,78	32,95	25,57	7,57	112,9	22
25	7,51	34,09	26,65	6,29	94,1	09
50	33	54	27,03	08	90,8	08
100	31	81	25	5,99	89,7	08
175	42	88	29	6,06	90,9	07

St. 130. 1927. VI 29 11^{45} a.m. 5′ NNW Björnsund (Buadypet)

1	11,18	30,93	23,60	6,75	106,9	8,25
10	9,71	33,01	25,47	7,05	109,7	23
25	7,09	34,02	26,66	6,73	99,7	13
50	08	47	27,01	38	94,7	09
100	30	94	35	05	90,6	08
150	48	35,07	42	02	90,6	07

St. 131. 1927. VI 29 2^{50} p.m. 17′ NW Björnsund (Buagrund)

1	10,64	32,83	25,16	6,69	106,0	8,21
10	23	90	29	72	105,7	22
25	7,52	34,05	26,62	41	95,9	14
40	13	51	27,03	07	90,4	09
75	20	85	29	...	...	08

St. 132. 1927. VI 29 6^{15} p.m. 32′ NW Björnsund (Banken)

1	10,59	33,12	25,42	6,54	106,0	8,25
10	39	19	49	57	105,9	25
25	8,13	34,18	26,63	7,06	106,9	24
50	6,99	67	27,18	6,16	91,3	09
120	7,53	35,14	48	16	92,7	08

St. 133. 1927. VI 29 9 p.m. 44′ NW Björnsund (Eggen)

1	10,50	33,44	25,67	6,67	108,1	8,25
10	51	55	75	74	109,5	24
25	9,07	35,21	27,30	...	...	23
50	02	32	38	6,70	104,2	19
100	8,65	32	44	20	95,8	14
200	7,85	23	50	35	96,2	14

s.s. SKAGERAK (Stat. 134—157).

St. 134. 1927. VII 31 6^{30} a.m. Julsund

0	14,89	24,81	18,20	...	...	8,27
10	11,30	32,70	24,95	...	...	23
20	9,18	33,58	26,01	...	...	16
30	8,40	95	41	...	...	10
40	7,78	34,23	73	...	...	08
60	32	61	27,02	...	...	07
80	29	65	12	...	...	07
100	24	70	17	...	...	06
175	30	81	16	...	...	04

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 135. 1927. VII 31 8^{30} a.m. 5′ NW Björnsund						
0	14,69	31,20	23,14	...	...	8,25
10	13,61	32,61	24,44	...	...	23
20	10,25	33,24	25,57	...	...	22
40	7,39	98	26,59	...	...	09
60	13	34,52	27,05	...	...	08
100	17	78	24	...	...	08
150	24	85	28	...	...	06
200	30	99	39	...	...	05
St. 136. 1927. VII 31 10^{30} a.m. 17′ NW Björnsund						
0	14,20	32,38	24,13	...	...	8,22
10	12,12	75	85	...	...	24
20	9,80	33,33	25,70	...	...	23
40	7,38	98	26,59	...	...	11
70	13	34,52	27,04	...	...	06
St. 137. 1927. VII 31 12^{50} a.m. 32′ NW Björnsund						
0	13,90	32,36	24,29	...	...	8,22
10	21	48	33	...	...	21
20	8,32	33,49	26,07	...	...	18
40	6,50	34,25	91	...	...	08
60	39	63	27,23	...	...	06
100	7,20	97	39	...	...	07
144	19	35,05	44	...	...	07
St. 138. 1927. VII 31 7^{30} p.m. 48′ NW Björnsund						
0	13,70	33,53	25,13	...	...	8,23
10	11,11	34,13	26,09	...	...	22
20	10,16	96	91	...	...	20
40	9,06	35,30	27,37	...	...	16
60	8,87	34	42	...	...	11
100	48	34	48	...	...	10
300	6,97	32	69	...	...	10
500	78	26	68	...	...	08
600	3,31	01	90	...	...	03
700	1,77	34,87	90	...	...	7,90
St. 139. 1927. VII 31 11 p.m. 75′ NW Björnsund						
0	14,34	33,84	25,24	...	...	...
10	13,56	34,11	61	...	...	...
20	11,17	81	26,62	...	...	...
40	8,26	35,28	27,47	...	...	...
60	7,96	30	54	...	...	...
100	53	32	61	...	...	...
280	6,73	23	65	...	...	...
480	2,50	03	97	...	...	...
680	+0,34	34,96	28,11	...	...	...
830	+ 69	88	06	...	...	...
St. 140. 1927. VIII 1 6^{30} a.m. 100′ NW Björnsund						
0	14,19	33,46	24,97	...	...	8,23
10	13,90	34,05	25,49	...	...	24
20	10,32	96	26,88	...	...	22
40	8,86	35,25	27,35	...	...	16
60	43	26	43	...	...	13
100	7,89	35,26	27,52	...	...	8,11
280	13	17	56	...	...	08
480	5,10	07	74	...	...	05
680	+0,43	34,85	98	...	...	...
830	+0,42	85	28,02	...	...	...
St. 141. 1927. VIII 1 10^{35} a.m. 125′ NW Björnsund						
0	14,14	34,14	25,52	...	...	8,27
10	13,24	43	92	...	...	27
20	9,44	35,23	27,24	...	...	21
40	7,83	14	43	...	...	13
60	96	23	48	...	...	14
100	46	25	56	...	...	13
280	6,81	16	59	...	...	10
480	2,08	34,90	91	...	...	04
680	+0,09	87	28,02	...	...	...
830	+ 44	85	00	...	...	...
St. 142. 1927. VIII 1 4^{40} p.m. 180′ NW Björnsund						
0	13,12	35,21	26,55	...	...	8,27
10	12,89	17	57	...	...	28
20	9,45	17	27,20	...	...	23
40	7,64	26	55	...	...	16
60	24	19	55	...	...	14
100	6,74	17	61	...	...	12
280	3,64	34,90	77	...	...	07
480	0,81	81	93	...	...	04
680	+0,20	83	28,00	...	...	...
830	+ 46	85	02	...	...	...
St. 143. 1927. VIII 1 11 p.m. 210′ NW Björnsund						
0	13,03	35,01	26,32	...	...	...
10	12,92	12	52	...	...	...
20	8,21	28	27,48	...	...	...
40	7,26	23	57	...	...	...
60	00	21	61	...	...	...
100	6,69	19	63	...	...	...
280	5,88	10	67	...	...	...
480	0,98	34,83	93	...	...	...
680	+0,17	85	28,01	...	...	...
830	+ 44	90	07	...	...	...
St. 144. 1927. VIII 4 8 p.m. 63°9′ N 6°1′ E						
0	14,18	32,30	24,09	...	...	...
10	14	54	28	...	...	...
20	10,40	33,44	25,69	...	...	...
30	8,10	60	26,16	...	...	...
40	7,36	84	47	...	...	...
50	6,76	34,20	84	...	...	...
60	85	67	27,20	...	...	...
70	97	78	27	...	...	...
80	7,15	88	31	...	...	...
St. 145. 1927. VIII 4 2 p.m. 63°15′ N 6°33′ E						
0	14,29	32,38	24,12	...	...	...
10	13,57	39	29	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
20	10,04	33,15	25,53	...	...	...
30	8,61	51	26,04	...	...	...
40	6,80	34,13	78	...	...	...
50	56	42	27,03	...	...	...
60	53	63	21	...	...	...
70	67	78	21	...	...	...
80	71	78	21	...	...	...

St. 146. 1927. VIII 4 5 p.m. 63°24′ N 6°5′ E

0	15,12	32,61	24,13	...	...	...
10	14,66	66	26	...	...	...
20	10,85	33,33	25,52	...	...	...
30	8,93	34,22	26,63	...	...	...
40	7,14	38	63	...	...	...
50	25	74	27,20	...	...	...
60	18	83	29	...	...	...
70	36	29	26,83	...	...	...
80	49	35,08	27,43	...	...	...
100	67	17	49	...	...	...
255	56	28	58	...	...	...

St. 147. 1927. VIII 4 8 pm. 63°18′ N 5°32′ E

0	14,16	32,72	24,41	...	...	...
10	13,35	33,35	25,07	...	...	...
20	11,55	48	51	...	...	...
30	10,48	78	26,72	...	...	...
40	56	35,19	27,02	...	...	...
50	9,64	21	20	...	...	...
60	7,76	34,94	28	...	...	...
70	86	35,03	34	...	...	...
80	8,02	14	40	...	...	...
100	7,78	17	47	...	...	...
160	55	21	53	...	...	...

St. 148. 1927. VIII 4 11 p.m. 63°3′ N 5°29′ E

0	14,86	32,34	23,97	...	...	...
10	06	41	24,20	...	...	...
20	9,36	33,26	25,71	...	...	...
30	7,57	75	26,38	...	...	...
40	78	34,16	81	...	...	...
50	6,54	38	27,02	...	...	...
60	56	49	09	...	...	...
70	59	65	22	...	...	...
80	61	74	29	...	...	...
100	74	87	47	...	...	...
158	7,17	35,07	47	...	...	...

St. 149. 1927. VIII 4 1^{20} a.m. 62°54′ N 5°58′ E

0	14,46	32,65	24,29	...	...	...
10	41	65	30	...	...	...
20	12,44	88	88	...	...	...
30	8,08	33,46	26,07	...	...	...
40	7,31	96	58	...	...	...
50	6,79	34,33	94	...	...	...
60	80	54	27,11	...	...	...
70	89	70	22	...	...	...
80	7,19	87	31	...	...	...
100	7,25	34,94	27,37	...	...	...
160	40	35,03	40	...	...	...

St. 150. 1927. VIII 4 4 a m. 63°9′ N 6°1′ E

0	14,17	32,27	24,07	...	...	...
10	16	30	25,09	...	...	...
20	9,71	33,33	12	...	...	...
30	7,18	80	26,43	...	...	...
40	6,68	34,38	27,00	...	...	...
50	82	60	15	...	...	...
60	7,04	76	24	...	...	...
70	05	79	27	...	...	...
80	21	88	32	...	...	...
100	16	94	36	...	...	...
129	26	96	37	...	...	...

St. 151. 1927. VIII 4 8 a.m. 63°0′ N 6°30′ E

0	14,68	32,27	23,96	...	...	...
10	37	30	24,05	...	...	...
20	9,51	33,35	25,77	...	...	...
30	8,05	86	26,38	...	...	...
40	7,07	34,36	52	...	...	...
50	02	49	27,03	...	...	...
60	07	56	08	...	...	...
70	07	58	10	...	...	...

St. 152. 1927. VIII 9 5^{00} a.m. 63°17′ N 5°27′ E

0	15,69	34,16	24,96	...	...	...
10	14,43	74	25,92	...	...	...
15	7,31	33,87	26,48	...	...	...
20	24	91	55	...	...	...
30	6,71	34,31	94	...	...	...
40	48	47	27,09	...	...	...
50	68	67	22	...	...	...
60	66	70	25	...	...	...
80	7,00	94	39	...	...	...
100	24	35,01	42	...	...	...
159	33	10	47	...	...	...

St. 153. 1927. VIII 9 9 a.m. 63°9′ N 5°56′ E

0	15,75	32,23	23,69	...	...	...
10	14,29	38	24,12	...	...	...
20	11,10	33,10	26,29	...	...	...
30	8,01	73	29	...	...	...
40	74	34,34	67	...	...	...
50	7,24	56	27,06	...	...	...
60	6,83	58	13	...	...	...
80	68	79	32	...	...	...
100	89	94	41	...	...	...
145	7,11	35,03	45	...	...	...

St. 154. 1927. VIII 9 10 a.m. 63°5′ N 5°50′ E

0	15,26	32,29	23,85	...	...	...
10	13,11	56	24,50	...	...	...
20	10,55	33,26	25,52	...	...	...
30	9,85	34,13	26,31	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
40	7,15	34,13	26,73	...	...	...
50	03	31	89	...	...	...
60	6,67	38	27,00	...	...	...
80	...	78	...	...	...	...
100	6,89	81	27,31	...	...	...
150	98	97	43	...	...	...
175	7,14	35,07	47	...	...	...

St. 155. 1927. VIII 9 2 p.m. 63°0′ N 5°24′ E

0	15,24	32,16	23,76	...	...	...
10	22	16	76	...	...	...
20	11,08	65	24,95	...	...	...
30	8,85	33,42	25,93	...	...	...
40	7,71	80	26,39	...	...	...
50	28	98	60	...	...	...
60	08	34,13	74	...	...	...
80	6,61	42	27,03	...	...	...
100	54	60	18	...	...	...
122	96	85	32	...	...	...

St. 156. 1927. VIII 9 5^{30} p.m. 63°9′ N 4°52′ E

0	15,28	32,79	24,23	...	...	...
10	14,25	34,76	25,96	...	...	...
20	12,84	35,07	26,49	...	...	...
30	9,16	34,96	27,07	...	...	...
40	8,96	35,10	22	...	...	...
50	6,80	34,85	34	...	...	...
60	76	85	35	...	...	...
80	8,69	35,26	39	...	...	...
100	76	35	45	...	...	...
150	08	28	40	...	...	...

St. 157. 1927. VIII 9 9 p.m. 63°23′5 N 5°5′ E

0	14,92	32,27	23,91	...	...	...
10	12,67	79	24,77	...	...	...
20	13,57	35,08	26,35	...	...	...
40	10,90	35	27,09	...	...	...
60	9,57	37	34	...	...	...
80	26	39	40	...	...	...
100	11	35	40	...	...	...
150	8,77	32	42	...	...	...

m.s. MORILD

St. 158. 1927. VIII 9 9^{30} a.m. 63°15′ N 6°6′ E

0	15,42	32,34	23,85	...	...	...
10	13,56	74	24,55	...	...	...
20	11,30	33,48	25,56	...	...	...
30	8,93	40	26,68	...	...	...
40	7,75	40	86	...	...	...
60	24	72	27,18	...	...	...
80	6,90	87	35	...	...	...
100	7,18	99	51	...	...	...
120	18	99	51	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H

St. 159. 1927. VIII 9 0^{45} p.m. 63°26′ N 6°1′ E

0	15,74	32,47	23,88	...	...	...
10	66	52	94	...	...	...
20	17,80	33,77	24,39	...	...	...
30	9,91	34,20	26,35	...	...	...
40	7,16	54	27,06	...	...	...
60	42	90	30	...	...	...
80	63	35,08	41	...	...	...
100	8,07	21	45	...	...	...
150	7,74	23	36	...	...	...
200	62	23	36	...	...	...
250	8,84	33,53	...	...	...	...

St. 160. 1927. VIII 9 2^{45} p.m. 63°30′ N 5°47′ E

0	15,23	32,74	24,20	...	...	...
10	22	79	25	...	...	...
20	9,66	33,82	26,10	...	...	...
30	8,00	34,40	73	...	...	...
40	60	90	27,13	...	...	...
60	79	35,21	34	...	...	...
80	50	25	40	...	...	...
100	71	32	43	...	...	...
150	7,74	25	52	...	...	...
200	70	25	53	...	...	...
250	63	26	56	...	...	...

St. 161. 1927. VIII 9 4^{30} p.m. 63°33′5 N 5°33′ E

0	14,92	32,59	24,16	...	...	...
10	96	61	16	...	...	...
20	11,76	33,33	25,36	...	...	...
30	7,94	87	26,42	...	...	...
40	18	34,22	79	...	...	...
60	6,50	65	27,23	...	...	...
80	9,52	33,42	25,84	...	...	...
100	8,91	35,28	27,37	...	...	...
150	72	32	43	...	...	...
200	16	23	45	...	...	...
250	7,51	21	53	...	...	...

St. 162. 1927. VIII 9 7 p.m. 63°31′5 N 5°6′ E

0	12,05	34,14	25,94	...	...	...
10	37	14	88	...	...	...
20	89	35,19	26,58	...	...	...
30	9,13	34,99	27,11	...	...	...
40	08	35,08	19	...	...	...
60	14	32	36	...	...	...
80	8,75	34	34	...	...	...
100	84	34	33	...	...	...
150	50	32	46	...	...	...
200	7,98	28	52	...	...	...
250	56	28	58	...	...	...

s.s. SKAGERAK (Stat. 163—180).

St. 163. 1927. VIII 15 4 a.m. 63°17′ N 5°27′ E

0	14,38	32,18	23,95	...	...	...
10	10	39	24,08	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
20	11,91	32,95	25,04	...	...	...
30	9,78	34,38	26,53	...	...	...
40	8,48	67	96	...	...	...
50	58	87	27,10	...	...	...
60	63	35,10	27	...	...	...
80	26	19	40	...	...	...
100	7,71	19	49	...	...	...
135	54	19	51	...	...	...
146	58	25	54	...	...	...

St. 164. 1927. VIII 15 5^{45} a.m. 63°12′ N 5°45′ E

0	14,41	32,25	24,00	...	...	...
10	38	39	12	...	...	...
20	11,56	33,28	25,36	...	...	...
30	7,44	86	26,47	...	...	...
40	31	34,38	91	...	...	...
50	92	72	27,09	...	...	...
60	6,66	67	23	...	...	...
80	69	87	38	...	...	...
100	92	97	43	...	...	...
135	7,16	35,08	48	...	...	...
141	16	12	50	...	...	...

St. 165. 1927. VIII 15 8 a.m. 63°21′ N 5°46′ E

0	13,97	32,34	24,16	...	...	...
10	96	39	20	...	...	...
15	97	43	23	...	...	...
20	10,34	33,15	25,48	...	...	...
30	7,47	86	26,47	...	...	...
40	10	34,29	86	...	...	...
50	6,91	52	27,08	...	...	...
60	7,60	76	15	...	...	...
80	64	35,08	41	...	...	...
100	81	12	41	...	...	...
135	69	16	46	...	...	...
175	59	17	49	...	...	...

St. 166. 1927. VIII 15 10 a.m. 63°17′ N 5°27′ E

0	14,16	32,36	24,14	...	...	...
10	10	36	15	...	...	...
15	12,99	61	56	...	...	...
20	8,60	33,78	26,25	...	...	...
30	7,11	34,20	79	...	...	...
40	6,80	38	98	...	...	...
50	75	42	27,01	...	...	...
60	86	65	18	...	...	...
80	7,57	35,05	39	...	...	...
100	42	05	41	...	...	...
135	6,58	12	59	...	...	...
156	7,60	16	48	...	...	...

St. 167. 1927. VIII 15 0^{15} p.m. 63°26′ N 5°26′5 E

0	14,08	32,32	24,13	...	...	...
10	12,76	72	70	...	...	...
15	9,65	33,42	25,80	...	...	...
20	17	34,13	26,42	...	...	...
30	7,26	34,45	26,96	...	...	...
40	8,19	88	27,17	...	...	...
50	71	35,14	30	...	...	...
60	9,56	37	34	...	...	...
80	26	39	40	...	...	...
100	15	39	42	...	...	...
135	8,89	35	43	...	...	...
175	80	25	36	...	...	...

St. 168. 1927. VIII 15 1^{15} p.m. 63°21′5 N 5°9′ E

0	14,23	32,36	24,12	...	...	...
10	33	34,09	25,43	...	...	...
15	18	27	61	...	...	...
20	13	42	72	...	...	...
30	10,16	35,08	26,97	...	...	...
40	8,34	34,83	27,01	...	...	...
50	7,46	87	27	...	...	...
60	64	35,01	34	...	...	...
80	8,67	34	45	...	...	...
100	54	30	45	...	...	...
135	03	28	51	...	...	...
175	7,64	28	56	...	...	...

St. 169. 1927. VIII 15 3^{30} p.m. 63°17′ N 5°27′ E

0	14,28	32,36	24,11	...	...	...
10	10	39	18	...	...	...
15	11,48	33,28	25,37	...	...	...
20	9,36	68	26,04	...	...	...
30	7,38	34,13	70	...	...	...
40	57	31	81	...	...	...
50	6,74	52	27,10	...	...	...
60	76	67	21	...	...	...
80	91	83	32	...	...	...
100	91	92	41	...	...	...
135	82	90	41	...	...	...
172	7,58	35,21	55	...	...	...

St. 170. 1927. VIII 15 5 p.m. 63°13′ N 5°8′ E

0	14,70	32,10	23,82	...	...	...
15	50	21	95	...	...	...
20	8,72	33,64	26,12	...	...	...
30	7,44	34,13	69	...	...	...
40	04	27	99	...	...	...
50	6,71	42	27,01	...	...	...
60	55	52	12	...	...	...
80	46	61	19	...	...	...
80	48	74	31	...	...	...
100	66	90	41	...	...	...
135	7,36	35,10	47	...	...	...
175	62	19	50	...	...	...

St. 171. 1927. VIII 15 6^{30} p.m. 63°8′ N 5°26′ E

0	14,48	32,25	23,98	...	...	...
10	52	39	24,09	...	...	...
15	11,96	99	25,06	...	...	...
20	7,76	33,98	26,53	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
30	7,18	34,23	26,81	...	...	...
40	6,76	40	99	...	...	...
50	67	47	27,08	...	...	...
60	67	60	17	...	...	...
80	63	67	23	...	...	...
100	7,98	35,07	35	...	...	...
135	14	08	48	...	...	...
175	44	21	54	...	...	...

St. 172. 1927. VIII 15 8 p.m. 63°17′ N 5°27′ E

0	14,17	32,38	24,14	...	...	...
10	12,72	77	74	...	...	...
15	10,00	33,66	25,92	...	...	...
20	8,50	34,23	26,62	...	...	...
30	6,96	33	91	...	...	...
40	79	40	99	...	...	...
50	72	42	27,01	...	...	...
60	80	69	26,68	...	...	...
80	7,08	88	27,33	...	...	...
100	29	35,01	40	...	...	...
135	45	12	47	...	...	...
157	45	19	52	...	...	...

St. 173. 1927. VIII 15 10 p.m. 63°12′ N 5°45′ E

0	14,47	32,32	24,04	...	...	...
10	30	32	08	...	...	...
15	13,58	52	38	...	...	...
20	8,14	62	26,20	...	...	...
30	7,48	33,87	49	...	...	...
40	26	34,27	82	...	...	...
50	6,64	40	27,01	...	...	...
60	68	63	19	...	...	...
80	7,14	96	38	...	...	...
100	37	35,01	40	...	...	...
135	09	01	44	...	...	...

St. 175. 1927. VIII 18 5^{10} a.m. Julsund

0	15,57	27,09	19,69	...	...	...
10	13,43	31,55	23,65	...	...	...
20	11,56	32,61	24,84	...	...	...
30	10,24	33,15	25,49	...	...	...
40	8,96	64	26,08	...	...	...
60	04	34,18	65	...	...	...
80	7,57	47	94	...	...	...
100	29	70	27,17	...	...	...
228	26	74	20	...	...	...

St. 176. 1927. VIII 18 6^{30} a.m. 5′ N Björnsund

0	15,27	31,38	23,15	...	...	...
10	14,42	32,14	90	...	...	...
20	12,30	54	24,54	...	...	...
40	9,67	33,28	25,69	...	...	...
60	7,76	87	26,45	...	...	...
100	30	34,54	27,04	...	...	...
150	26	88	31	...	...	...
160	26	88	31	...	...	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H

St. 177. 1927. VIII 18 8^{30} a.m. 17′ N Björnsund

0	15,11	31,40	23,19	...	...	...
10	14,78	32,00	74	...	...	...
20	9,15	33,42	25,88	...	...	...
40	6,82	34,29	26,90	...	...	...
70	7,06	85	27,31	...	...	...

St. 178. 1927. VIII 18 10^{30} a.m. 32′ N Björnsund

0	14,83	32,00	23,72	...	...	...
10	66	12	85	...	...	...
20	9,23	33,66	26,05	...	...	...
30	36	34,11	38	...	...	...
40	7,22	47	99	...	...	...
60	58	88	27,25	...	...	...
80	08	97	40	...	...	...
100	30	35,08	45	...	...	...
140	27	08	45	...	...	...

St. 179. 1927. VIII 18 1 p.m. 48′ N Björnsund

0	15,44	31,31	23,06	...	...	...
10	12,76	33,26	25,11	...	...	...
20	13,93	34,85	26,10	...	...	...
30	9,26	32,43	25,09	...	...	...
40	7,06	34,74	27,23	...	...	...
60	6,74	81	33	...	...	...
80	7,06	35,07	48	...	...	...
100	46	14	48	...	...	...
150	52	17	57	...	...	...
300	29	21	57	...	...	...
500	13	25	60	...	...	...

St 180. 1927. VIII 18 5 p.m. 63°17′ N 5°27′ E

0	15,46	31,33	23,07	...	...	...
10	08	71	44	...	...	...
20	9,80	33,39	25,65	...	...	...
30	7,78	34,29	26,77	...	...	...
40	19	38	93	...	...	...
50	6,55	58	27,17	...	...	...
60	61	79	33	...	...	...
80	7,06	96	39	...	...	...
100	06	96	39	...	...	...
135	36	35,12	49	...	...	...
153	44	14	49	...	...	...

St. 201. 1928. III 13 12^{45} p.m. 5′ NNW Björnsund

1	4,36	33,33	26,44	7,28	100,7	8,17
10	31	40	50	38	102,0	14
25	51	42	51	24	100,6	18
40	49	44	52	22	100,2	14
75	5,11	75	70	18	101,4	13
125	6,02	34,58	27,24	22	105,4	13
175	54	65	36	6,41	94,3	10

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 202. 1928. III 13 4 p.m. 17′ NW Björnsund (Buagrund)						
1	4,21	33,33	26,46	7,29	100,4	8,12
10	18	33	46	41	102,1	11
25	29	48	57	18	99,2	15
40	91	60	61	6,95	97,5	14
75	5,15	34,16	27,02	82	96,7	12
St. 203. 1928. III 13 7^{50} p.m. 32′ NW Björnsund (Banken)						
1	4,42	33,48	26,56	7,32	101,4	...
10	41	49	57	33	101,5	...
25	42	49	57	30	101,1	...
40	5,19	84	76	00	99,2	...
75	77	34,29	27,05	6,88	99,1	...
120	6,43	76	33	64	97,5	...
St. 205. 1928. III 14 9 a.m. Julsund						
1	3,73	33,13	26,35	7,73	103,7	8,17
10	81	17	37	51	100,9	16
25	4,02	30	45	52	103,2	15
40	34	37	47	28	100,7	14
75	5,17	77	70	6,52	89,99	14
125	6,11	34,38	27,08	...	...	12
200	42	54	16	6,41	93,78	10
St. 206. 1928. III 26 12^{10} p.m. 5′ NNW Björnsund (Buadypet)						
1	4,16	33,24	26,40	7,86	108,1	8,17
10	31	33	45	62	105,3	18
25	41	39	49	30	101,1	15
40	46	44	53	24	100,4	13
75	5,31	96	84	6,86	97,44	12
125	6,01	34,45	27,14	69	97,09	12
175	30	65	25	51	95,32	11
St. 207. 1928. III 26 3^{50} p.m. 17′ NW Björnsund (Buagrund)						
1	4,33	33,33	26,45	7,88	108,8	8,16
10	83	73	66	23	101,4	14
25	5,08	86	78	6,97	98,45	12
40	28	34,04	90	93	98,42	11
75	6,06	49	27,16	59	95,77	10
St. 208. 1928. III 26 7^{30} p.m. 32′ NW Björnsund (Banken)						
1	4,22	33,21	26,36	7,57	104,1	...
10	23	26	40	61	105,0	...
25	38	53	60	24	102,8	...
40	69	66	66	28	101,7	...
75	5,96	34,61	27,19	6,61	95,77	...
120	6,42	83	38	57	96,50	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H
St. 209. 1928. III 26 11^{10} p.m. 47′ NW Björnsund (Eggen)						
1	7,41	35,32	27,63	6,67	100,5	...
10	43	34	66	65	100,1	...
25	39	35	66	68	100,5	...
40	37	37	68	7,12	107,1	...
75	32	37	69	6,69	100,5	...
150	12	37	72	69	100,0	...
250	6,86	32	71	73	100,0	...
400	5,41	21	82	69	98,29	...
St. 211. 1928. III 27 11^{30} a.m. Julsund						
1	4,09	33,03	26,23	8,25	113,0	8,24
10	16	21	36	7,84	107,8	18
25	21	30	43	89	108,7	17
40	25	33	45	62	105,1	15
75	5,35	82	71	6,78	96,43	12
125	89	34,31	27,04	66	96,25	11
200	6,01	42	11	46	93,76	09
St. 212. 1928. III 27 3^{45} p.m. 62°42′5 N 7°0′ E						
1	4,30	32,90	26,10	8,61	118,6	8,24
10	3,96	33,06	27	71	119,0	24
25	4,19	21	36	7,63	105,0	16
40	31	30	42	33	101,1	14
75	6,22	89	67	6,27	91,01	12
150	91	34,36	95	5,87	86,84	12
250	7,10	70	27,20	57	83,03	11
400	29	78	23	49	82,18	09
St. 213. 1928. VII 28 7^{10} a.m. 46′ NW Björnsund (Eggen)						
1	10,25	34,54	26,58	7,00	111,4	8,32
10	58	99	87	6,73	108,0	24
25	23	88	84	37	101,6	18
40	8,06	76	27,09	20	94,4	13
75	15	35,21	44	20	94,7	13
150	72	19	34	38	98,6	11
350	6,66	08	56	32	93,5	10
650	÷0,07?	34,88	28,03	80	85,1	7,98
St. 214. 1928. VII 28 12^{10} p.m. 32′ NW Björnsund (Banken)						
1	9,96	34,27	26,41	7,27	114,7	...
10	41	58	74	12	111,4	...
25	83	35,25	27,18	6,30	99,8	...
40	8,39	08	29	28	95,9	...
75	7,09	21	60	27	93,7	...
120	6.75	12	56	20	91,8	...
St. 215. 1928. VII 28 3^{15} p.m. 17′ NW Björnsund (Buagrund)						
1	9,75	33,96	26,20	6,64	104,1	8,22
10	69	34,16	37	90	108,1	21
25	8,79	87	27,07	40	98,9	15

m	$t°$	S ‰	σ_t	O_2	M %	p_H
40	8,08	34,90	27,21	6.28	95,6	8.12
75	7,04	35,10	52	18	91,1	09

St. 216. 1928. VII 28 6^{30}p.m. 5′NNW Björnsund (Buadypet)

1	11,39	32,48	24,77	6,46	103,9	8,29
10	10,92	33,08	25,32	47	103,1	27
25	60	21	47	24	99,0	26
40	32	82	26,00	57	104,0	25
75	7,32	34,74	19	01	90,1	12
150	20	35,19	27,56	12	91,6	11

St. 217. 1928. VII 28 8^{30}p.m. Julsund

1	11,61	30,28	23,03	6,58	104,7	8,24
10	10,67	32,81	25,15	23	98,9	18
25	56	33,01	32	23	98,7	17
40	41	15	46	23	98,6	16
75	7,72	34,54	26,01	5,93	88,8	10
175	19	94	27,37	99	89,7	09

St. 220. 1928. VIII 14 6^{15}p.m. 5′NNW Björnsund (Buadypet)

1	12,61	31,74	23,97	5,90	96,5	8,28
10	43	32,25	24,40	99	97,9	24
25	10,43	33,42	25,68	77	91,4	19
40	9,91	75	26,01	80	91,0	17
75	7,12	34,79	26	57	82,6	09
150	8,41	92	27,16	56	85,2	09

St. 221. 1928. VIII 14 9^{05}p.m. 17′NW Björnsund (Buagrund)

1	12,74	32,32	24,40	5,61	92,2	...
10	51	48	56	76	94,3	...
25	9,18	34,42	26,65	6,06	94,3	...
40	8,41	79	27,07	5,73	87,9	...
65	7,12	35,03	44	56	82,9	...

St. 222. 1928. VIII 15 0^{15}a.m. 32′NW Björnsund (Banken)

1	12,52	32,79	24,80	5,77	94,8	...
10	19	95	25,00	85	95,8	...
25	9,10	34,85	26,98	85	91,2	...
40	04	35,26	27,34	62	87,7	...
75	8,30	26	45	74	88,1	...
120	7,26	16	53	80	87,0	...

m	$t°$	S ‰	σ_t	O_2	M %	p_H

St. 223. 1928. VIII 15 5^{25}a.m. 46′NW Björnsund (Eggen)

1	12,30	33,13	25,11	5,85	95,8	8,28
10	11,98	31	31	92	96,6	26
25	8,92	34,87	27,05	95	90,0	16
40	89	35,26	36	64	87,5	14
75	82	26	37	66	87,8	13
150	7,93	23	54	76	87,5	12
350	37	16	52	78	86,8	12

St. 224. 1928. VIII. 15 3^{30}p.m. Julsund

1	13,65	28,48	21,26	6,02	98,2	8,24
10	10,71	32,43	24,86	5,99	95,0	22
25	10	84	25,27	87	92,1	21
40	8,61	33,93	26,35	59	85,5	12
75	7.56	34,72	27,14	51	82,9	09
175	27	99	39	56	83,3	09

St. 225. 1928. VIII 21 1^{30}a.m. 48′NW Björnsund (Eggen)

1	12,67	32,36	24,43	...	...	...
25	9,92	34,90	26,91	...	...	...
100	8,93	35,34	27,41	...	...	...
200	35	28	46	...	...	...

St. 226. 1928. VIII 21 5^{15}a.m. 75′NW Björnsund

1	12,33	33,55	25,42	...	...	...
25	11,40	34,94	26,67	...	...	...
100	8,30	35,28	27,46	...	...	...
200	7,33	21	56	...	...	...

St. 227. 1928. VIII 21 9^{30}a.m. 110′NW Björnsund

1	11,72	34,92	26,50	...	...	...
25	31	96	70	...	...	...
100	8.50	35,32	27,46	...	...	...
200	7,38	23	56	...	...	...

St. 228. 1928. VIII 21 2^{45}p.m. 145′NW Björnsund

1	11,80	34,94	26,60	...	...	...
25	05	35,07	84	...	...	...
100	7,81	26	27,53	...	...	...
200	6,98	25	63	...	...	...

St. 229. 1928. VIII 21 6^{50}p.m. 180′NW Björnsund

1	10,88	35,01	26,83	...	...	...
25	9,95	12	27,07	...	...	...
100	6,59	12	59	...	...	...
200	3,49	05	89	...	...	...

Table II. Dynamic tables giving:

anomalies of sp. vol. ($10^5\,\delta$)

and anomalies of dyn. depth $\left(10^4\,\Delta D = 10^4 \int_0^p \delta\, dp\right)$

for standard pressures.

p	$10^5\,\delta$	$10^4\,\Delta D$
Station 135.		
0	474	0
10	349	412
20	244	708
30	196	928
40	148	1100
50	126	1237
60	104	1352
70	99	1454
80	95	1551
90	90	1643
100	86	1731
150	82	2129
200	73	2526
Station 136.		
0	378	0
10	311	345
20	230	616
30	189	825
40	148	994
50	133	1134
60	119	1260
70	104	1372
Station 137.		
0	378	0
10	351	365
20	195	638
30	156	813
40	116	949
50	101	1058
60	86	1151
70	82	1235
80	79	1316
90	75	1393
100	72	1466
140	67	1744
Station 138.		
0	281	0
10	192	237
20	115	390
30	94	494
40	74	579
50	71	651
60	68	721
70	67	788
80	65	854
90	64	919
100	63	982
140	...	1218
200	55	1572
300	47	2082
400	49	2562
500	51	3062
600	28	3457
700	25	3722
Station 152.		
0	278	0
10	210	244
15	153	335
20	149	410
30	113	541
40	99	647
50	86	740
60	84	825
70	78	906
80	72	980
90	70	1052
100	69	1121
150	66	1459
Station 153.		
0	422	0
10	380	401
20	268	725
30	174	946
40	140	1103
50	102	1224
60	95	1323
70	86	1413
80	78	1495
90	74	1571
100	71	1644
150	67	1989
Station 154.		
0	406	0
10	344	375
20	248	671
30	173	882
40	133	1035
50	117	1160
60	108	1272
70	97	1375
80	86	1466
90	83	1551
100	80	1632
150	69	2005
Station 155.		
0	416	0
10	415	416
20	301	774
30	210	1029
40	166	1217
50	146	1373
60	132	1512
70	118	1637
80	104	1748
90	97	1849
100	91	1943
125	78	2154
Station 156.		
0	371	0
10	204	288
20	155	467
30	100	595
40	86	688
50	75	768
60	74	843
70	73	916
80	72	989
90	69	1059
100	66	1127
150	63	1449
Station 157.		
0	399	0
10	318	359
20	168	602
30	134	753
40	100	870
50	88	964
60	77	1046
70	74	1121
80	72	1195
90	71	1266
100	71	1337
150	70	1690
Station 158.		
0	405	0
10	339	372
20	244	664
30	139	855
40	122	986
50	105	1099
60	89	1196
70	82	1282
80	76	1360
90	73	1435
100	71	1507
120	71	1649
Station 159.		
0	403	0
10	397	400
20	354	776
30	168	1037
40	102	1172
50	91	1268
60	80	1354
70	75	1431
80	70	1504
90	68	1573
100	66	1640
150	61	1957
200	60	2260
250	60	...
Station 160.		
0	374	0
10	369	372
20	192	652
30	125	811
40	97	922
50	87	1014
60	76	1095
70	73	1170
80	70	1241
90	69	1311
100	68	1379
150	60	1699
200	61	2002
250	59	2302

p	$10^5\delta$	$10^4\Delta D$
Station 161.		
0	376	0
10	375	376
20	263	695
30	163	908
40	126	1052
50	106	1186
60	86	1264
70	154	1384
80	221	1572
90	148	1756
100	74	1867
150	69	2225
200	68	2567
250	60	2887
Station 162.		
0	208	0
10	213	211
20	149	392
30	98	515
40	90	609
50	82	695
60	74	773
70	71	846
80	67	914
90	67	982
100	68	1049
150	66	1384
200	63	1706
250	57	2007
Station 163.		
0	396	0
10	375	386
20	292	719
30	153	942
40	111	1073
50	99	1179
60	81	1269
70	76	1347
80	71	1421
90	67	1490
100	63	1555
135	61	1772
Station 164.		
0	391	0
10	381	386
20	263	708
30	160	920
40	116	1058
50	98	1165
60	86	1257
70	79	1339
80	72	1415
90	70	1486
100	68	1555
135	63	1784
Station 165.		
0	376	0
10	372	374
15	369	559
20	251	714
30	158	918
40	120	1057
50	101	1168
60	92	1264
70	81	1351
80	71	1426
90	70	1496
100	69	1566
135	53	1802
175	64	2060
Station 166.		
0	378	0
10	377	378
15	338	556
20	179	686
30	126	839
40	110	957
50	106	1064
60	92	1164
70	81	1250
80	71	1326
90	70	1396
100	69	1466
135	53	1680
156	64	1914
Station 167.		
0	380	0
10	325	353
15	220	489
20	161	584
30	111	720
40	92	822
50	79	907
60	77	985
70	75	1061
80	72	1135
90	71	1206
100	70	1277
135	69	1520
175	77	1812
Station 168.		
0	380	0
10	256	318
15	239	442
20	228	559
30	110	728
40	98	831
50	83	922
60	74	1001
70	70	1072
80	66	1141
90	66	1207
100	67	1273
135	62	1499
175	58	1739
Station 169.		
0	381	0
10	375	378
15	261	537
20	197	650
30	137	817
40	125	948
50	99	1060
60	87	1153
70	83	1238
80	79	1318
90	75	1396
100	72	1469
135	73	1722
175	60	1989
Station 170.		
0	407	0
10	396	402
15	190	548
20	136	630
30	120	758
40	105	870
50	97	971
60	88	1064
70	84	1150
80	80	1232
90	75	1309
100	71	1382
135	64	1618
175	62	1870
Station 171.		
0	393	0
10	383	388
15	291	557
20	152	667
30	126	806
40	108	923
50	101	1028
60	91	1124
70	88	1213
80	85	1300
90	80	1382
100	85	1460
135	63	1701
175	58	1943
Station 172.		
0	377	0
10	320	349
15	208	480
20	143	568
30	116	697
40	109	810
50	105	917
60	87	1013
70	82	1097
80	77	1177
90	74	1252
100	70	1324
135	65	1560
150	62	1656
Station 173.		
0	387	0
10	384	386
15	356	571
20	183	705
30	157	875
40	124	1015
50	106	1131
60	90	1229
70	81	1314
80	72	1391
90	71	1462
100	71	1533
135	67	1775

Table III. Current observations July—August 1927.

69°9′ N. 6°1′ E. Depth 15 m. Currentmeter E 13.

Date	GCT	Direction (true) from	Velocity cm./sec.
31/7	16,59	S 10°W	14
»	17,30	—	25
»	18,00	—	26
»	30	S 30°W	29
»	19,01	S 30°W	29
»	31	S 60°W	30
»	20,01	S 60°W	31
»	31	S 70°W	29
»	21,02	W	28
»	32	N 80°W	23
»	22,02	—	19
»	33	S 70°W	13
»	23,03	S 60°W	13
»	33	S 20°W	11
1/8	0,04	—	11
»	34	—	12
»	1,04	E	14
»	34	S 65° E	15
»	2,05	S 70° E	18
»	35	S 70° E	18
»	3,05	S 55° E	20
»	35	S 50° E	21
»	4,06	N 45° E	22
»	36	S 50° E	22
»	5,06	S 50° E	24
»	37	S 30° E	25
»	6,07	S 50°W	24
»	37	S 20°W	24
»	7,07	S 20°W	24
»	38	S 50°W	24
»	8,08	S 50°W	22
»	38	—	7
»	9,09	S 70°W	20
»	39	W	20
»	10,09	W	17
»	39	S 70°W	17
»	11,10	S 70°W	15
»	40	S 50°W	13
»	12,10	S 40°W	11
»	41	N 30° E	12
»	13,11	N 60° E	10
»	42	—	12
»	14,11	S 80° E	15
»	42	S 85° E	19
»	15,12	S 25° E	22
»	42	S 40° E	23
1/8	16,13	S 20° E	23
»	43	S 20° E	25
»	17,13	S 10° E	24
»	43	S	25
»	18,14	S 10°W	35
»	44	S 20°W	35
»	19,14	S 10°W	37
»	45	S 40°W	40
»	20,15	S 50°W	41
»	45	S 50°W	44
»	21,15	S 55°W	48
»	46	S 65°W	47
»	22,16	S 70°W	48
»	46	S 60°W	43
»	23,17	S 70°W	37
»	47	—	32
2/8	0,17	—	22
»	47	W	22
»	1,18	N 70°W	18
»	48	—	16
»	2,18	N 10°W	11
»	49	N 10°W	11
»	3,19	N 10° E	12
»	49	N	10
»	4,19	N 50° E	»
»	50	S 30° E	»
»	5,20	S 20° E	21
»	50	—	22
»	6,21	—	23
»	51	S 10° E	24
»	7,21	S 30°W	25
»	51	S 30°W	28
»	8,22	S 40°W	26
»	52	S 40°W	28
»	9,22	S 30°W	26
»	53	S 50°W	23
»	10,23	S 55°W	31
»	53	S 50°W	26
»	11,23	S 60°W	24
»	54	S 55°W	24
»	12,24	S 60°W	17
»	54	S 35°W	14
»	13,24	—	13
»	55	N 5° E	13
»	14,25	N 10° E	13
»	55	N 70° E	14
2/8	15,26	...	16
»	56	S 70° E	17
»	16,26	S 60° E	16
»	56	S 50° E	27
»	17,27	S 40° E	26
»	57	S 60° E	25
»	18,27	S 20° E	23
»	58	S 10° E	27
»	19,28	S 5° W	32
»	58	S 10°W	35
»	20,28	S 20°W	36
»	59	S 30°W	40
»	21,29	S 30°W	45
»	59	S 50°W	46
»	22,30	S 65°W	39
»	23,00	S 55°W	41
»	30	S 70°W	38
3/8	0,00	S 80°W	37
»	31	W	34
»	1,01	S 75°W	32
»	31	—	29
»	2,02	—	24
»	32	—	22
»	3,02	N 80°W	21
»	32	S 60°W	20
»	4,03	S 60°W	15
»	33	S 45°W	16
»	5,03	—	18
»	34	—	18
»	6,04	S 35°W	21
»	34	—	23
»	7,04	S 70°W	21
»	35	—	23
»	8,05	S 60°W	25
»	35	S 40°W	25
»	9,06	S 40°W	26
»	36	S 40°W	27
»	10,06	S 45°W	31
»	36	S 40°W	35
»	11,07	S 75°W	38
»	37	S 85°W	39
»	12,07	S 85°W	39
»	37	N 85°W	40
»	13,08	W	40
»	38	N 80°W	39
»	14,08	W	39
			35

Date	GCT	Direction (true) from	Velocity cm./sec.
3/8	14,39	W	35
»	15,09	S 40° W	33
»	39	S 60° W	28
»	16,09	—	25
»	40	—	23
»	17,10	S 60° W	21
»	40	—	19
»	18,11	—	38
»	41	—	18
»	19,11	S 20° W	17
»	41	—	17
»	20,12	—	18
»	42	—	4
»	21,12	S 30° W	25
»	43	S 30° W	24
»	22,13	S 40° W	27
»	43	S 40° W	28
»	23,14	S 60° W	29
»	44	S 30° W	30
4/8	0,14	S 40° W	28
»	44	S 30° W	28
»	1,15	S 30° W	31
»	45	S 60° W	30
»	2,15	S 50° W	30
»	45	S 40° W	30
»	3,16	S 40° W	30
»	46	S 55° W	27
»	4,16	—	24
»	47	S 70° W	21
»	5,17	S 70° W	21
»	47	—	19
»	6,17	—	19
»	48	N 80° W	17
»	7,18	S 80° W	16
»	48	—	15
»	8,19	—	16
»	49	—	16
»	9,19	—	19
»	49	S 20° E	19
»	10,20	S 10° E	20
»	50	S 5° E	26
»	11,20	S 20° E	25
»	51	S 30° E	23
»	12,21	S 20° E	23
»	12,51	—	26
»	13,21	S 10° W	24
»	52	S 20° W	27
»	14,22	S 10° W	29
»	52	S 25° W	28
»	15,23	S 20° W	28
»	53	S	23
»	16,23	S 40° W	24
»	53	—	22
»	17,24	—	20
»	54	S 30° W	19
			22

Date	GCT	Direction (true) from	Velocity cm./sec.
4/8	18,24	S 40° W	22
»	55	S 30° W	20
»	19,25	S 30° W	18
»	55	—	17
»	20,25	S 50° W	16
»	56	S 40° W	17
»	21,26	S 60° W	19
»	56	—	17
»	22,27	S 70° W	16
»	57	—	18
»	23,27	S 50° W	20
»	57	S 55° W	19
5/8	0,28	S 50° W	18
»	58	S 40° W	17
»	1,28	S 40° W	20
»	59	S 40° W	19
»	2,29	S 20° W	19
»	59	S 25° W	23
»	3,29	S 25° W	24
»	4,00	S 20° W	24
»	30	S 30° W	25
»	5,00	S 20° W	24
»	30	—	25
»	6,01	S 35° W	23
»	31	S 45° W	22
»	7,01	S 50° W	20
»	32	S 50° W	23
»	8,02	S 60° W	21
»	32	S 60° W	20
»	9,03	S 65° W	18
»	33	S 60° W	20
»	10,03	S 50° W	19
»	33	S 60° W	20
»	11,04	S 50° W	20
»	34	S 40° W	20
»	12,04	S 55° W	20
»	34	S 50° W	21
»	13,05	S 70° W	20
»	35	S 50° W	19
»	14,05	S 50° W	17
»	35	S 40° W	16
»	15,06	S 50° W	16
»	36	S 30° W	16
»	16,06	S 35° W	17
»	37	S 25° W	18
»	17,07	S 40° W	18
»	37	S 10° W	19
»	18,08	S 10° W	18
»	38	S 30° E	21
»	19,08	S 10° W	19
»	38	S 20° W	18
»	20,09	S 50° W	18
»	39	S 50° W	19
»	21,09	S 50° W	19
»	40	S 60° W	19
			20

Date	GCT	Direction (true) from	Velocity cm./sec.
5/8	22,10	S 60° W	20
»	40	—	18
»	23,10	S 55° W	17
»	41	S 75° W	19
6/8	0,11	—	18
»	41	—	16
»	1,12	S 60° W	16
»	42	S 50° W	17
»	2,12	S 70° W	17
»	42	S 70° W	15
»	3,13	S 75° W	14
»	43	S 50° W	13
»	4,13	S 20° W	12
»	43	S 40° W	10
»	5,14	S 10° E	11
»	44	S 10° W	11
»	6,14	S	12
»	45	S 5° E	15
»	7,15	S	17
»	45	S	19
»	8,15	S 10° W	21
»	46	S 15° W	21
»	9,16	S 30° W	19
»	46	S 40° W	18
»	10,17	S 70° W	19
»	47	S 60° W	18
»	11,17	N 80° W	18
»	48	S 60° W	16
»	12,18	S 50° W	16
»	48	S 50° W	14
»	13,18	S 60° W	14
»	49	S 40° W	12
»	14,19	S 5° W	11
»	49	S 75° E	10
»	15,19	S 50° E	10
»	50	S 80° E	14
»	16,20	S 60° E	16
»	50	S 45° E	16
»	17,21	S 35° E	20
»	51	S 20° E	23
»	18,21	S 10° E	24
»	51	S	24
»	19,22	S	26
»	52	S 15° W	27
»	20,22	S 20° W	28
»	53	S 30° W	27
»	21,23	S 40° W	29
»	53	S 40° W	30
»	22,23	S 40° W	29
»	54	S 60° W	29
»	23,24	S 55° W	27
»	54	S 60° W	27
7/8	0,25	S 75° W	23
»	55	S 70° W	20
»	1,25	S 65° W	16
			15

Date	GCT	Direction (true) from	Velocity cm./sec.
7/8	1,55	N 75°W	15
»	2,26	—	13
»	56	W	12
»	3,26	S 50°W	11
»	57	S 50°W	11
»	4,27	—	10
»	57	S 10° E	10
»	5,27	S 20°W	13
»	58	S 40°W	14
»	6,28	—	15
»	58	—	17
»	7,29	S 20° E	18
»	59	S 10° E	21
»	8,29	S 10° E	22
»	9,00	S 5° E	24
»	30	S 5° E	27
»	10,00	S 5°W	29
»	30	S 15°W	27
»	11,01	S 30°W	31
»	31	S 30°W	30
			27
7/8	12,01	S 30°W	27
»	32	S 40°W	26
»	13,02	S 45°W	25
»	32	S 55°W	24
»	14,03	S 65°W	24
»	33	S 65°W	21
»	15,03	S 75°W	19
»	33	N 80°W	16
»	16,04	—	17
»	34	N 50°W	17
»	17,04	N 35°W	13
»	34	N	13
»	18,05	N 60° E	13
»	35	N 80° E	14
»	19,05	N 80° E	15
»	36	S 80° E	17
»	20,06	S 65° E	20
»	36	S 40° E	23
»	21,07	S 30° E	27
»	37	S 20° E	29
			33
7/8	22,07	S	33
»	37	S 5°W	37
»	23,08	S 10°W	39
»	38	S 20°W	43
8/8	0,08	S 30°W	41
»	38	S 40°W	39
»	1,09	S 50°W	38
»	39	S 70°W	30
»	2,09	S 80°W	28
»	39	W	27
»	3,10	W	22
»	40	N 75°W	19
»	4,10	N 65°W	16
»	41	N 60°W	15
»	5,11	N 50°W	12
»	41	N 30°W	8
»	6,11	E	8
»	41	N 70° E	8
»	7,12	S 80° E	11
»	42	S 55° E	15
			20

63°9′ N. 6°1′ E. Depth 71 m. Currentmeter E 12.

Date	GCT	Direction (true) from	Velocity cm./sec.
31/7	15,58	S 30° E	11
»	16,28	S 20° E	9
»	57	S 10° E	10
»	17,27	N 70°W	7
»	57	S 15° E	7
»	18,27	S 15° E	7
»	56	S 15° E	10
»	19,26	S 50°W	8
»	56	S 55°W	10
»	20,26	S 20°W	8
»	55	S 45°W	8
31/7	21,25	S 40°W	8
»	55	S 50°W	8
»	22,24	S 20° E	7
»	54	S 20° E	8
»	23,24	S 10° E	9
»	54	S 20° E	8
1/8	0,23	S 35° E	8
»	53	S 25° E	10
»	1,23	S 30° E	5
»	53	S 60° E	6
			8
1/8	2,22	S 60° E	8
»	52	S 55° E	7
»	3,22	S 50° E	11
»	52	S 55° E	10
»	4,21	S 65° E	7
»	51	S 75° E	7
»	5,21	S 55° E	8
»	50	S 40° E	7
»	6,20	S	8
»	50	S 25° E	6

63°17′ N. 5°27′ E. Depth 15 m. Currentmeter E 13.

Date	GCT	Direction (true) from	Velocity cm./sec.
8/8	17,13	N 75° E	3
»	43	E	3
»	18,13	S 80° E	8
»	44	N 80° E	12
»	19,14	E	12
»	44	S 80° E	12
»	20,14	S 70° E	15
»	44	S 60° E	21
»	21,15	S 40° E	20
»	45	S 40° E	20
»	22,15	S 30° E	18
»	45	S 15° E	22
»	23,16	S 10° E	20
»	46	S 10° E	16
9/8	0,16	S	15
9/8	0,46	S 20°W	15
»	1,16	S 30°W	13
»	47	—	13
»	2,17	S 40°W	11
»	47	S 50°W	15
»	3,17	—	14
»	48	N 85°W	13
»	4,18	—	13
»	48	N 40°W	8
»	5,18	N 30°W	10
»	48	N 30°W	5
»	6,19	N 30° E	2
»	49	N 70° E	3
»	7,19	N 50° E	4
»	49	S 70° E	6
			4
9/8	8,20	S 40° E	4
»	50	S 10° E	5
»	9,20	S 10° E	6
»	50	S 20° E	5
»	10,20	—	7
»	51	S 10° E	10
»	11,21	—	10
»	51	—	12
»	12,21	S 10°W	14
»	52	S 10°W	17
»	13,22	S 40°W	19
»	52	S 35°W	18
»	14,22	S 60°W	24
»	52	S 60°W	28
»	15,23	S 60°W	24
			31

Date	GCT	Direction (true) from	Velocity cm./sec.
$^{9}/_{8}$	15,53	S 60° W	31
»	16,23	S 75° W	26
»	53	S 75° W	22
$^{12}/_{8}$	5,20	—	
»	50	S 20° E	14
»	6,20	S 10° E	14
»	51	S 30° W	17
»	7,21	S 10° W	16
»	51	S	22
»	8,21	S	22
»	51	S 5° W	24
»	9,22	S 10° W	24
»	52	S 20° W	27
»	10,22	S 30° W	29
»	52	S 20° W	33
»	11,23	S 20° W	33
»	53	S 10° W	33
»	12,23	S 30° W	34
»	53	S 20° W	36
»	13,23	S 25° W	38
»	54	S 30° W	38
»	14,24	S 30° W	36
»	54	S 50° W	34
»	15,24	S 50° W	32
»	55	S 30° W	31
»	16,25	S 60° W	33
»	55	S 60° W	30
»	17,25	S 60° W	23
»	55	S 50° W	22
»	18,26	S 50° W	24
»	56	S 40° W	23
»	19,26	S 60° W	24
»	56	S 60° W	25
»	20,27	S 30° W	22
»	57	S 40° W	23
»	21,27	S 25° W	21
»	57	S	20
»	22,27	S 20° W	21
»	58	S 20° W	23
»	23,28	S 10° W	23
»	58	S 20° W	29
$^{13}/_{8}$	0,28	S 30° W	25
»	59	S 10° E	25
»	1,29	S 10° W	22
»	59	S	27
»	2,29	S 20° W	29
»	59	S 40° W	32
»	3,30	S 40° W	30
»	4,00	S 60° W	30
»	30	S 50° W	30
»	5,00	S 50° W	29
»	30	S 60° W	26
»	6,01	S 70° W	28
»	31	S 80° W	23
»	7,01	S 75° W	22
			20

Date	GCT	Direction (true) from	Velocity cm./sec.
$^{13}/_{8}$	7,31	N 80° W	20
»	8,02	S 80° W	16
»	32	S 50° W	14
»	9,02	S 10° W	14
»	32	S 10° E	16
»	10,03	S 10° E	19
»	33	S 10° E	19
»	11,03	S 10° E	22
»	33	S 20° E	23
»	12,03	S 20° E	27
»	34	S 30° E	29
»	13,04	S 30° E	36
»	34	S 10° E	38
»	14,04	S	42
»	34	S 10° W	42
»	15,05	S 20° W	41
»	35	S 20° W	40
»	16,05	S 30° W	47
»	35	S 40° W	45
»	17,06	S 40° W	39
»	36	S 55° W	38
»	18,06	S 60° W	34
»	36	S 60° W	31
»	19,07	S 70° W	27
»	37	S 50° W	23
»	20,07	S 60° W	23
»	37	S 60° W	20
»	21,07	S 50° W	18
»	38	S 50° W	14
»	22,08	—	11
»	38	S 85° E	8
»	23,08	S 50° E	10
»	39	S 40° E	14
$^{14}/_{8}$	0,09	S 20° E	20
»	39	S 20° E	23
»	1,09	S 30° E	27
»	39	S 10° E	23
»	2,10	S 10° E	23
»	40	S	29
»	3,10	S 5° E	34
»	40	S 10° W	38
»	4.11	S 10° W	34
»	41	S 25° W	33
»	5,11	S 30° W	33
»	41	S 30° W	31
»	6,11	S 50° W	30
»	42	S 70° W	30
»	7,12	—	30
»	42	N 75° W	25
»	8,12	N 75° W	27
»	43	N 80° W	25
»	9,13	N 80° W	23
»	43	N 75° W	21
»	10,13	—	10
»	43	N 55° E	9
			13

Date	GCT	Direction (true) from	Velocity cm./sec.
$^{14}/_{8}$	11,14	N 85° E	13
»	44	S 80° E	13
»	12,14	E	16
»	44	S 75° E	13
»	13,15	S 70° E	32
»	45	S 60° E	26
»	18,17	S 40° W	
»	47	S 60° W	14
»	19,17	S 70° W	41
»	47	—	36
»	20,17	W	36
»	48	N 80° W	30
»	21,18	N 80° W	26
»	48	N 75° W	22
»	22,18	N 70° W	20
»	48	S 75° E	11
»	23,19	N 40° W	9
»	49	S 40° E	18
$^{15}/_{8}$	0,19	N 85° E	9
»	49	E	14
»	1,19	S 80° E	22
»	49	S 80° E	22
»	2,20	S 70° E	26
»	50	S 70° E	26
»	3,20	S 60° E	21
»	50	S 40° E	24
»	4,21	S 10° E	25
»	51	S 20° W	25
»	5,21	S 50° W	23
»	51	S 60° W	21
»	6,21	S 60° W	20
»	52	S 65° W	16
»	7,22	S 75° W	17
»	52	W	14
»	8,22	S 80° W	13
»	53	W	10
»	9,23	S 80° E	10
»	53	—	9
»	10,23	S 80° E	9
»	53	S 80° E	11
»	11,24	S 50° E	18
»	54	S 40° E	18
»	12,24	—	18
»	54	S 20° E	21
»	13,24	S 30° E	21
»	55	S 20° E	23
»	14,25	S 20° E	25
»	55	S 10° E	26
»	15,25	S 30° E	22
»	55	S 10° E	22
»	16,26	S 30° E	22
»	56	S 10° W	23
»	17,26	S 20° W	22
»	56	S 40° W	22
»	18,26	S 60° W	29
			33

Date	GCT	Direction (true) from	Velocity cm./sec.
15/8	18,57	S 50°W	33
»	19,27	S 60°W	36
»	57	S 50°W	29
»	20,27	S 60°W	24
»	57	S 70°W	25
»	21,28	S 80°W	39
»	58	—	18
»	22,28	N 70°W	27
»	58	N 60°W	17
»	23,28	—	12
»	59	W	9
16/8	0,29	E	9
»	59	E	12
»	1,29	S 80° E	19
»	59	S 70° E	22
»	2,30	S 50° E	25
»	3,00	S 40° E	24
»	30	S 20° E	25
»	4,00	S 20°W	16
»	30	S 40°W	13
»	5,01	S 50°W	13
»	31	S 30°W	18
»	6,01	S 50°W	21
»	31	S 65°W	20
»	7,01	—	23
»	32		25
»	8,02	—	22
»	32	S 70°W	31
»	9,02	W	25
»	32	—	30
»	10,03	S 75°W	35
»	33	S 70°W	32
»	11,03	S 75°W	25
»	33	S 75°W	20
»	12,03	S 80°W	16
»	34	S 80°W	14
»	13,04	W	9
»	34	S 80°W	7
»	14,04	S 60°W	6
»	34	S 50°W	8
»	15,05	S 20° E	9
»	35	S 20° E	10
»	16,05	S 50° E	14
»	35	S 50° E	21
»	17,05	S 35° E	22
»	36	S 15° E	19
»	18,06	S 5° E	23
			22

Date	GCT	Direction (true) from	Velocity cm./sec.
16/8	18,36	S 10°W	22
»	19,06	S 10°W	22
»	37	S 60°W	21
»	20,07	S 20°W	26
»	37	S 20°W	14
»	21,07	S 40°W	28
»	37	S 50°W	24
»	22,08	S 50°W	23
»	38	S 40°W	18
»	23,08	S 40°W	16
»	38	—	13
17/8	0,08	S 40°W	14
»	39	S 15°W	15
»	1,09	S 20° E	13
»	39	S 10° E	14
»	2,09	S	21
»	39	S	28
»	3,10	S 5°W	30
»	40	S 25°W	33
»	4,10	S 30°W	29
»	40	—	29
»	5,10	—	28
»	41	S 10°W	24
»	6,11	S 30°W	22
»	41	S 30°W	29
»	7,11	S 40°W	25
»	41	S 40°W	29
»	8,12	S 60°W	27
»	42	—	20
»	9,12	S 50°W	20
»	42	S 40°W	24
»	10,12	S 30°W	22
»	43	S 20°W	23
»	11,13	S 20° E	24
»	43	S 5°W	30
»	12,13	S 10°W	40
»	43	S 10°W	33
»	13,14	S 5°W	36
»	44	S 10°W	36
»	14,14	S	41
»	45	S	41
»	15,15	S 10°W	40
»	45	S 10°W	38
»	16,15	S 10°W	31
»	45	S 20°W	30
»	17,16	S 40°W	31
»	46	S 30°W	31
			31

Date	GCT	Direction (true) from	Velocity cm./sec.
17/8	18,16	S 20°W	31
»	46	S 30°W	34
»	19,14	S 40°W	29
»	46	S 30°W	30
»	20,16	—	23
»	47	S 50°W	25
»	21,17	S 50°W	25
»	47	S 60°W	23
»	22,17	S 65°W	25
»	47	S 70°W	26
»	23,18	S 70°W	24
»	48	S 70°W	15
18/8	0,18	S 50°W	14
»	48	S 30°W	15
»	1,18	S 15°W	15
»	49	S 10°W	16
»	2,19	S 20° E	21
»	49	S 20° E	21
»	3,19	S 20° E	22
»	49	S 20° E	23
»	4,20	S	27
»	50	S 5°W	35
»	5,20	S 10°W	36
»	50	S 30°W	34
»	6,21	S 40°W	36
»	51	S 40°W	16
»	7,21	S 40°W	21
»	51	S 70°W	19
»	8,21	N 80°W	16
»	52	W	13
»	9,22	W	10
»	52	S 80°W	12
»	10,22	S 70°W	13
»	52	S 10°W	7
»	11,23	S 60° E	9
»	53	S 60° E	14
»	12,23	S 50° E	18
»	53	S 60° E	20
»	13,23	S 50° E	5
»	54	S 40° E	40
»	14,24	S 30° E	27
»	54	S 25° E	31
»	15,24	S 20° E	31
»	54	S 15° E	27
»	16,25	S	22
»	55	S	34
			27

63′17 N. 5°27′ E. Depth 134 m. Currentmeter E 12.

8/8	16,37	N 77°W	12
»	17,07	N 85°W	8
»	37	W	4
8/8	18,07	S 88°W	4
»	36	S	2
»	19,06	S	2
			2
8/8	19,36	S 70° E	2
»	20,05	S 15° E	3
»	35	S 15° E	3
			7

Date	GCT	Direction (true) from	Velocity cm./sec.
8/8	21,05	S 15° E	7
»	35	S 15° E	7
»	22,04	S 25° W	8
»	34	S 35° W	8
»	23,04	S 35° W	8
»	34	S 55° W	10
9/8	0,03	S 58° W	10
»	33	S 65° W	10
»	1,03	S 72° W	12
»	33	S 75 W	15
»	2,02	S 80° W	15
»	32	S 85° W	16
»	3,02	S 86° W	16
»	31	W	15
»	4,01	W	12
»	31	N 81° W	10
»	5,01	N 80° W	10
»	30	N 75° W	8
»	6,00	N 75° W	4
»	30	S 20° E	0
»	7,00	S 75° E	0
»	29	S 67° E	4
»	59	S 60° E	8
»	8,29	S 50° E	11
»	58	S 45° E	13
»	9,28	S 45° E	15
»	58	S 20° E	15
»	10,28	S 20° E	20
»	57	S 18° E	22
»	11,27	S 10° E	21
»	57	S	21
»	12,27	S 15° W	23
»	56	S 30° W	24
»	13,26	S 40° W	23
»	56	S 45° W	23
»	14,26	S 46° W	22
»	55	S 75° W	23
»	15,25	W	22
»	55	N 85° W	23
»	16,24	W	20
»	54	N 85° W	18
»	17,24	W	16
»	54	S 85° W	14
»	18,23	S 85° W	12
»	53	S 78° W	11
»	19,23	S 55° W	12
»	53	S 50° W	12
»	20,22	S 45° W	11
»	52	S 36° W	11
»	21,22	S 30° W	12
»	51	S 30° W	12
»	22,21	S 45° W	12
»	51	S 60° W	12
»	23,21	S 60° W	11
»	50	S 80° W	12
			13

Date	GCT	Direction (true) from	Velocity cm./sec.
10/8	0,20	S 80° W	13
»	50	S 87° W	14
»	1,19	N 80° W	15
»	49	N 80° W	16
14/8	17,13	S 45° W	28
»	43	S 56° W	26
»	18,12	S 56° W	27
»	42	S 65° W	29
»	19,12	S 82° W	29
»	42	S 87° W	26
»	20,11	W	25
»	41	S 86° W	27
»	21,10	S 86° W	25
»	40	S 86° W	22
»	22,09	S 87° W	24
»	39	S 87° W	9
»	23,09	S 86° W	11
»	38	W	6
15/8	0,08	S 4° E	3
»	38	S 10° E	3
»	1,08	S 30° E	6
»	37	S 40° E	9
»	2,07	S 54° E	10
»	37	S 50° E	17
»	3,07	S 43° E	14
»	36	S 40° E	13
»	4,06	S 30° E	16
»	36	S 30° E	17
»	5,06	S 20° E	18
»	35	S 10° E	19
»	6,05	S	18
»	35	S 30° W	22
»	7,04	S 40° W	24
»	34	S 45° W	25
»	8,04	S 58° W	23
»	34	S 85° W	22
»	9,03	N 86° W	19
»	33	N 85° W	18
»	10,03	N 85° W	12
»	33	S 85° W	9
»	11,02	S 65° W	6
»	32	S 10° E	7
»	12,02	S 10° E	10
»	31	S 10° E	12
»	13,01	S 10° E	14
»	31	S 20° E	16
»	14,01	S 20° E	18
»	30	S 20° E	23
»	15,00	S 20° E	25
»	30	S 10° E	25
»	16,00	S 10° E	28
»	30	S 10° E	29
	59	S 10° E	31
»	17,29	S	32
»	59	S 30° W	35

Date	GCT	Direction (true) from	Velocity cm./sec.
15/8	18,29	S 40° W	35
»	58	S 65° W	36
»	19,28	S 80° W	31
»	58	S 86° W	27
»	20,27	N 84° W	29
»	57	N 82° W	26
»	21,27	N 84° W	27
»	57	N 84° W	23
»	22,26	N 84° W	21
»	56	S 84° W	18
»	23,26	S 85° W	12
»	56	S 50° W	9
16/8	0,25	S 10° E	6
»	55	S 10° E	7
»	1,25	S 10° E	9
»	54	S 10° E	13
»	2,24	S 10° E	18
»	54	S 20° E	17
»	3,24	S 20° E	19
»	53	S 10° E	20
»	4,23	S 10° E	21
»	53	S 10° E	25
»	5,23	S 10° E	26
»	52	S 25° W	22
»	6,22	S 50° W	23
»	52	S 55° W	25
»	7,22	S 80° W	27
»	51	N 86° W	24
»	8,21	N 85° W	24
»	51	N 84° W	24
»	9,20	N 85° W	22
»	50	S 85° W	18
»	10,20	S 70° W	15
»	50	S 70° W	12
»	11,19	S 40° W	9
»	49	S 10° E	8
»	12,19	S 10° E	10
»	49	S 20° E	13
»	13,18	S 30° E	16
»	48	S 30° E	19
»	14,18	S 30° E	23
»	47	S 30° E	27
»	15,17	S 20° E	31
»	47	S 20° E	31
»	16,17	S 20° E	35
»	46	S 10° E	36
»	17,16	S 10° E	37
»	46	S 10° E	37
»	18,16	S 20° W	38
»	45	S 44° W	41
»	19,15	S 60° W	39
»	45	S 70° W	37
»	20,15	S 80° W	31
»	45	S 85° W	31
»	21,14	S 85° W	28
			26

Date	GCT	Direction (true) from	Velocity cm./sec.
16/8	21,44	S 85°W	26
»	22,13	W	24
»	43	W	22
»	23,13	W	19
»	43	W	13
17/8	0,12	S 84°W	9
»	42	S 20°W	3
»	1,12	S 85° E	0
»	42	S 73° E	5
»	2,11	S 60° E	10
»	41	S 56° E	13
»	3,11	S 45° E	19
»	40	S 40° E	25
»	4,10	S 40° E	25
»	40	S 30° E	29
»	5,10	S 20° E	30
»	39	S 20° E	26
»	6,09	S 10° E	30
»	39	S 10° E	31
»	7,09	S 10° E	29
»	38	S 6° E	31
»	8,08	S 20°W	33
»	38	S 55°W	31
»	9,08	S 60°W	33
»	37	S 85°W	24
»	10,07	W	21
»	37	W	20
»	11,06	W	20
			17

Date	GCT	Direction (true) from	Velocity cm./sec.
17/8	11,36	S 86°W	17
»	12,06	W	10
»	36	S 10° E	5
»	13,05	S 20° E	5
»	35	S 30° E	10
»	14,05	S 30° E	14
»	35	S 30° E	17
»	15,04	S 35° E	20
»	34	S 30° E	23
»	16,04	S 20° E	26
»	33	S 20° E	29
»	17,03	S 20° E	36
»	33	S 10° E	31
»	18,03	S 10° E	33
»	32	S	36
»	19,02	S 30°W	32
»	32	S 40°W	32
»	20,02	S 50°W	34
»	31	S 50°W	36
»	21,01	S 70°W	36
»	31	S 80°W	31
»	22,01	S 83°W	29
»	30	W	26
»	23,00	W	24
»	30	W	23
»	59	S 86°W	15
18/8	0,29	S 80°W	15
»	59	S 64°W	9
			8

Date	GCT	Direction (true) from	Velocity cm./sec.
18/8	1,29	S 28°W	8
»	58	S 2° E	9
»	2,28	S 10° E	9
»	58	S 10° E	9
»	3,28	S 10° E	11
»	57	S 30° E	13
»	4,27	S 30° E	17
»	57	S 26° E	19
»	5,27	S 27° E	20
»	56	S 20° E	18
»	6,26	S 10° E	18
»	56	S 5° E	18
»	7,25	S 16°W	19
»	55	S 24°W	21
»	8,25	S 35°W	25
»	55	S 45°W	22
»	9,24	S 55°W	21
»	54	S 85°W	22
»	10,24	N 86°W	21
»	54	N 80°W	24
»	11,23	N 80°W	22
»	53	N 75°W	20
»	12,23	N 75°W	16
»	52	N 70°W	12
»	13,22	N 70°W	10
»	52	N 50°W	6
»	14,22	N 26°W	4
»	51	N 23°W	4
			6

QUANTITATIVE PLANKTON INVESTIGATIONS CARRIED OUT DURING THE EXPEDITION WITH THE "MICHAEL SARS", JULY—SEPT. 1924

BY

H. H. GRAN

As a member of the expedition on board the "Michael Sars" in July—September 1924, I collected throughout the whole of the voyage water samples for quantitative investigation of the plankton by means of the centrifuge. The samples were preserved partly with FLEMING's liquid, partly with sublimate; the former is best for diatoms, peridineans and ciliate infusoria, but is useless for coccolithophorids. Preservation with sublimate gives serviceable results with diatoms, peridineans and cocolithophorids, but is not so good for infusoria. It has also the disadvantage that when preserved for some time, crystals often develop, rendering investigation difficult and results less accurate.

The method has been worked out for coastal waters, where diatoms and peridineans are altogether predominant. With these organisms, as experience has shown, it gives entirely satisfactory results, when it is a question of investigating the quantitative variations of the dominant species. And in investigating the conditions for production of organic matter, much can be attained by the study of these variations. It is practically impossible to arrive at a quantitative determination of all the organisms found in the same water mass with the accuracy desired, and even if it could be done, the result would be of little scientific value. Investigating with the greatest possible accuracy the total plankton content of a single water sample from the Canary Current or from the North Sea, as UTERMÖHL (1927) has attempted to do, is about as valuable as carrying out a single temperature determination to the third decimal point. It is only by comparing the qualitative and quantitative variations for a larger area, or variations at the same place in the course of a season, that we can arrive at any connection between the occurrence of the plankton and the external conditions of life. And the material will then be so extensive that one is obliged to simplify the work by confining oneself to the quantitative variations of selected leading forms, arranging the method of investigation accordingly.

Under oceanic conditions, and especially in the warmer waters, a difficulty arises in that we loose a whole series of small forms, the classification and development of which have not yet been sufficiently determined. Moreover, no quite satisfactory method has yet been worked out for the quantitative determination of these small forms; and we have here to reckon with the objections raised by Allen (1919) and Utermöhl (1927) against the effectiveness of the centrifuge method. It can, undoubtedly, be arranged with special regard to the smaller forms,

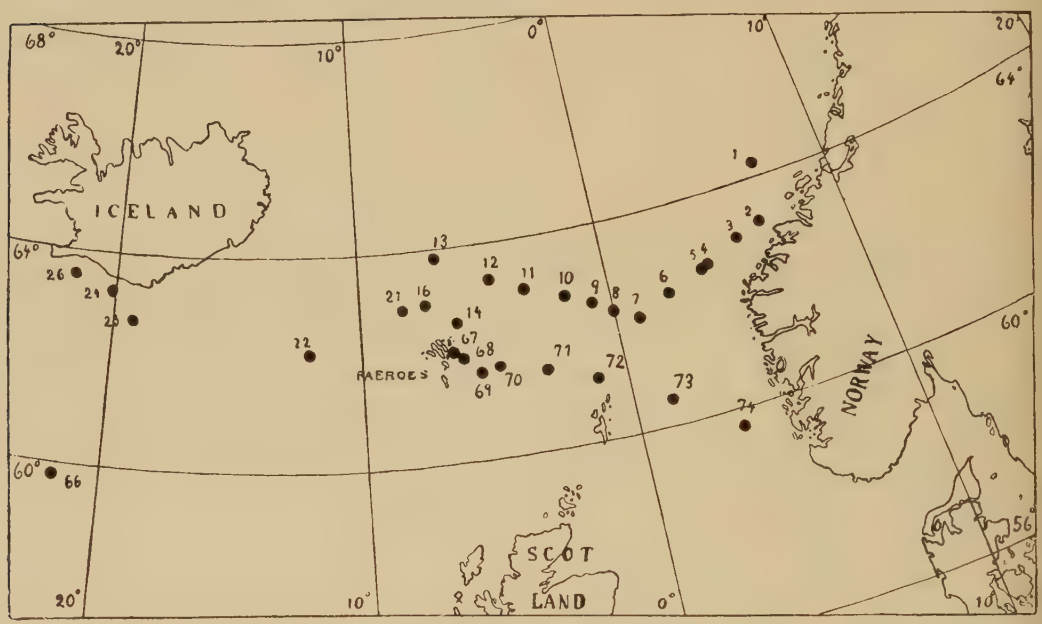

Fig. 1.

as has been demonstrated, in practice, by Lohmann; this, however, requires particularly favourable conditions for working; the samples must be examined shortly after preservation, while the colour is still comparatively unchanged. Centrifugation of samples with living organisms is not to be recommended, partly because the sedimentation in a living state is less reliable, and partly because several forms rapidly become disorganised under the cover glass, as Wulff (1926) has shown in the case of *Mesodinium* and other infusoria. This applies not only to the centrifuge method, but also to any other sedimentation or filtration method which could be considered as at all adaptable to the purpose.

Of the material collected during the crossing of the Norwegian Sea, only a small portion was dealt with on the voyage, so that all the nannoplankton forms could be satisfactorily determined in fresh samples. At stations with highest temperature and salinity especially, i.e. in pure Gulf Stream water, these species were

dominant. The pure blue of the water itself, with a faint but distinct milky tinge, was a sure sign that coccolithophorids, with their highly refractive calcareous shells, must be present in great numbers.

I think it right here to restrict myself to the mention of some few data showing the order of magnitude for the density of these species.

At Station 4, on the edge outside Söndmöre, the temperature at 10 m. was 10.30°, salinity 35.25 ‰, the water a pure blue, milky. We found here a number of diatoms, both oceanic species such as *Nitzschia delicatissima* (13500 pr. l.) and *seriata* (3400), *Chaetoceras currens* (1000), *convolutum* (1900) and *peruvianum* (400), *Corethron criophilum* (200) and neritic species such as *Rhizosolenia Stolterfothii* (5000) a distinct sign of importation from Scotland. Dominant: *Pontosphaera Huxleyi*, with 84500 pr. l., and in lesser degree *Coccolithophora leptopora* with 900. Peridineans and infusoria were altogether subordinate.

Station 10, temperature at 10 m. 9.70°, salinity 35.13 ‰. Poorer plankton, *Pontosphaera Huxleyi* 6400 pr. l., *Coccolithophora pelagica* 60. Diatoms in small quantities, *Rhizosolenia styliformis* 230, *Chætoceras boreale* (single cells), *convolutum*, *currens* and *peruvianum*, *Corethron criophilum*. Peridineans: small numbers of ceratia *C. longipes* 100, *C. arcticum* 20; infusoria: *Cyttarocyclis denticulata* to the number of 540 pr. l.

Station 11, temperature at 10 m. 8.91°, salinity 34.99 ‰. *Coccolithophora pelagica* 3720, *Ceratium arcticum* 360; of infusoria especially *Laboea strobila* (140).

Station 13, temperature at 10 m. 7.40°, salinity 34.87 ‰. *Coccolithophora pelagica* 80, *Ceratium arcticum* 180, *Rhizosolenia styliformis* 1140, *Thalassiothrix longissima* 820, *Laboea strobila* 1760.

Station 14, temperature at 10 m. 9.29°, salinity 35.21 ‰. *Pontosphaera Huxleyi* 53600, *Coccolithophora pelagica* 80. *Ceratium fusus* 30, naked flagellates observed 5600, diatoms sparsely, (*Corethron* 80, *Rhizosolenia styliformis* 40). Infusoria few.

Station 16, temperature at 10 m. 9.83°, salinity 35.25 ‰. *Pontosphaera Huxleyi* 23600, *Coccolithophora* 260, *Ceratium fusus* 20, *Corethron* 300, *Chaetoceras boreale* 260, infusoria few.

These examples show that in the warm Atlantic water masses in the Norwegian Sea in July, *Pontosphaera Huxleyi* is the most important, or at any rate one of the most important, producers. Where the salinity falls below 35 ‰, it gives place rather to the diatoms, which, however, are nowhere met with in any quantity comparable to what we find in the coastal waters. Ceratia are, throughout the area investigated, of altogether subordinate importance in quantitative respects. Considering the small amount of plankton present it is remarkable that we find a supersaturation with oxygen at the surface at all stations from the coast of Norway to and including Stations 13, N.W. of the Faroes and 14, due north of the islands in question. The phenomenon may be due in some degree to heating of the surface layers, as all the observations were made in the first half of July

(July 9th—14th); on the other hand, all the water masses are moving northward, and should thus rather be in process of cooling. The supersaturation amounts to 107—108 %, at Station 7, where temperature and salinity were highest of all, to as much as 110 %. Here the p_H value at the surface attains its maximum, 8.27. The surplus of oxygen over and above what would correspond to saturation comes to over 0.6 cc. per. l. and lies at most stations between 0.4 and 0.6 cc. in the productive surface layers which ought to correspond to a very considerable production. The p_H values are also correspondingly high. But we cannot, from a single series of such observations, say anything as to how long it has taken to build up this surplus of oxygen, nor do we know anything as to how rapidly such a surplus may be dissipated by interchange of gas with the atmosphere. It seems certain, however, that the nannoplankton, and most of all *Pontosphaera Huxleyi*, are, in these waters during summer, of very essential importance as effective producers of organic matter.

A clearer view is obtained when we endeavour to judge, from the distribution of the oxygen, as to the depth to which production exceeds the expenditure of oxygen by respiration. Of the 10 stations 4—13 inclusive, seven, viz. 4, 7, 8, 9, 10, 12, and 13 have their point of equilibrium (oxygen 100 % of saturation at a pressure of 1 atmosphere) between 25 and 50 m. or at 50 m. depth. At a single station, 5, it lies at 100 m., at Station 6 a little below 50 and at Station 11 between 10 and 25 m. The distribution of the p_H values runs on the whole parallel with this; at depths corresponding to those given we find, with few and immaterial exceptions, the greatest differences in p_H value.

We should then be able to assert that the balance between assimilation and dissimilation in this area in summer lies between 25 and 50 m.; variations may be due to fluctuations in the transparency of the water. The principal exceptions are Station 5, where we find supersaturation to 75 m. inclusive, and saturation at 100 m. depth, and Station 11, where marked supersaturation was observed at 1—10 m., but subsaturation at the slight depth of 25 m. In the latter case we find, between 10 and 25 m., a sudden change in temperature, salinity and density; σ_τ at 1 m. is 27.11, at 10 m. 27.14 and at 25 m. 27.70. The light, heated surface layer is here unusually thin; the subjacent layers, of greater density, are much poorer in plankton than the surface water. At Station 5, on the other hand, the density is low, and uniform down to 50 m. inclusive (σ_τ 27.08—27.10); at none of the other stations do we find such a low value for σ_τ so far down. It is natural therefore here to imagine a thickening of the surface layers, and we may perhaps assert that the exceptions prove the rule.

At the stations (67—74) taken on the return voyage September 2nd—4th, the plankton was altogether very poor, and the surface layers show but slight if any supersaturation with oxygen; few coccolithorphorids were found, as a rule only very few diatoms, and of ceratia, never more than 200 pr. l. of all species

together (at St. 73). An interesting exception is Station 67, on the Faroe Bank itself; here we find a fairly rich diatom plankton with *Nitzschia seriata* as the dominant species. And the plankton is evenly distributed from surface to bottom; the same even distribution is also apparent in temperature, salinity, oxygen content and p_H; everything suggests that a lively vertical circulation has taken place here, resulting in the richer plankton development through the introduction of food material from the bottom and from the deeper layers.

The accompanying table shows how evenly the species are distributed; the variations lie but a little way beyond the limits of error for the method:

Station 67. 1924, September 2. 62° 2′ 30″ N. Lat. 6° 41′ W. Long.

Depth	Temperature	Salinity	σ_t	Oxygen, cc. pr. l.	Oxygen % of saturation	p_H	Chætoceras debile	Navicula distans	Nitzschia seriata	Paralia sulcata	Rhizosolenia alata	Rhizosolenia Shrubsolei	Thalassiosira gravida	Thalassiothrix nitzschioides
1	9.52	35.08	27.11	6.09	96.0	8.11	80	160	25800	1400	300	100	20	380
20	9.50	35.08	27.11	6.14	96.0	8.10	200	120	38420	720	480	200	100	280
40	9.50	35.09	27.12	6.12	96.0	8.10	280	100	32920	1360	460	620	140	360
60	9.50	35.10	27.12	6.06	95.5	8.10	120	120	34280	1880	800	160	80	400
80	9.47	35.10	27.14	6.06	95.5	8.10	260	140	68700	1020	820	720	80	560
100	9.46	35.10	27.14	6.06	95.5	8.10	—	20	42680	1360	200	540	200	160

Precisely on the Faroe Bank the same phenomenon was observed on the May 31st, 1912, (Gran 1915, p. 120), and Paulsen (1911) has earlier noted that the comparatively rich plankton here must be due to the introduction of nourishment from the deep layers by vertical circulation.

Otherwise — apart from the area west of Greenland — a rich diatom plankton was only found at 2 stations due south of Reykjavik, Iceland (St. 24 and 25); the *Asterionella* plankton previously known from Ostenfeld's investigations (1899) was met with here. At Station 24, on the July 21st, for instance, at 10 metres, the dominant species were found to be *Chætoceras debile* 87640 pr. l., *Ch. compressum* 60960, *Asterionella japonica* 26320 and in addition a whole series of other species, chiefly neritic, amounting together to close on 240,000 diatoms pr. l.

Attention was principally devoted to the investigation of Davis Strait; we might here expect to find material for the solution of the problem as to the influence of ice on plankton development; moreover, during this part of the cruise, we were favoured by calm weather, so that we were able to examine most of the samples on board. Here also the plankton was of such a character that the centrifuge method was practicable throughout; the plankton consisted altogether predominantly of diatoms and peridineans, the nannoplankton forms being altogether

subordinate in comparison save at a single oceanic station (58) where the larger forms were very scarce. The only species which it was difficult to determine quantitatively was the flagellate *Dinobryon pellucidum*, and this was dominant at some few stations. Its colonies evinced a tendency to dissolve into fragments, and after some weeks of preservation might fall to pieces altogether, leaving only single cells.

Test experiments with the centrifuge method show that the source of error involved by vortex formation in the tubes, as mentioned by Wulff (1926) and Utermöhl (1927) can be avoided altogether if care is taken first to ensure that the motion is not too suddenly checked, and tubes with a narrow bottom part used, and the clear liquid drawn up cautiously with a pipette. I generally stop the drawing off when the liquid is abt. $^1/_2$ cm. above the sediment, and then centrifuge the rest once more to allow any cells set in motion by the pipette to subside. The entire remainder of the covering liquid can then be drawn off at one time, and, if carefully done, without involving any movement of the sediment. When the sediment is then drawn up together with a suitable quantity of liquid to fill a preparation under a cover glass 20 mm. square, there will of course be some cells left clinging to the bottom of the tube, and in the pipette. Previously, I used to rinse pipette and tube with distilled water and centrifuge this rinsing water in order to make a fresh count of the residue, adding this to the first result. It was found, however, that most species left fairly accurately 10 %, and I have therefore simplified the method to the extent of increasing the volume of the original liquid by 10 % and thus for instance instead of centrifuging 50 cc., have taken 55 cc. It is then possible to reckon the result of the count as representing, without essential error, the true content of 50 cc. Where individual species occur in very great numbers, these should be examined in a separate sample of 10, 5 or even 1 cc.; it is not advisable to examine only a small number of rows under the cover glass, as the contents under the cover glass is rarely evenly distributed.

Plankton Production in Davis Strait. Previous Investigations.

The first work on plankton samples from this water was published by Cleve (1896). He investigated especially the diatoms in a series of samples from Davis Strait and Baffins Bay, collected in May—October 1894 by a relief expedition sent out to look for the unfortunate Swedish explorers Björling and Kalstenius. Cleve's work is primarily systematic; he notes altogether 38 species of plankton diatoms, among which several were described as new. The zooplankton in the same samples, including the peridineans, has been dealt with by Aurivillius (1896).

In May the dominant species north of Disco were arctic-neritic forms such as *Fragilaria oceanica* and *cylindrus* and *Lauderia glacialis* together with the oceanic *Coscinodiscus oculus iridis*. In June—August, in Melville Bay and round Bylot Island, at 72—73° N., abt. 74° W., the dominant species were *Ceratium arcticum*

and at another place, near Carey Island, on the July 24th, *Thalassiosira Nordenskioldii*. At Bylot Island, in the middle of August, *Ceratium arcticum* was superseded by a rich diatom plankton with *Chaetoceras diadema* (*Ch. groenlandicum* Cleve) as dominant species. This association remained in force until past the middle of September. In October, in the northern part of Davis Strait, great quantities of diatoms were also found, with *Thalassiosira Nordenskiöldii* as dominant species, and together with this, oceanic forms such as *Chaetoceras atlanticum* and *Thalassiothrix longissima*. It is particularly interesting to note that Cleve discovered the occurrence of ice-diatoms in the rich Ceratium plankton of Baffins Bay. He boiled one of these plankton samples with acid, and thus obtained a whole series of species of diatoms which he knew already from the Vega expedition's material from Cape Wankarema (Cleve 1883) and which he regarded as characteristic of the polar ice. The same species were also found in the material from the polar ice collected by Nansen during the expedition of 1893—96. (Gran 1900). When therefore we find these species floating among the plankton in summer in Baffins Bay, it is natural to conclude that they originate from melted polar ice, even though it need not have drifted all the way from the coast of Siberia.

The earliest quantitative investigations are those of Vanhöffen (1897) who examined the plankton production of Little Karajak Fjord in Greenland (a little over 70° N.) throughout a whole year, 1892—93. The fjord was covered with ice from December 1st to the beginning of June; but as early as March the diatoms began to collect on the underside of the ice. According to the determination given by Gran (1897) the species were partly true plankton forms such as *Fragilaria oceanica* and *Navicula septentrionalis*, partly ice-forms such as *Nitzschia frigida* and *N. hybrida*.

On the May 23rd, a characteristic "Taenio-plankton" was observed, consisting of arctic-neritic species (*Fragilaria oceanica* and *cylindrus*, *Achnanthes taeniata*, *Navicula septentrionalis* and *Vanhoeffenii*, *Amphipora hyperborea*, *Melosira hyperborea*, *Thalassiosira Nordenskiöldii* and *hyalina*).

In July—August, *Thalassiosira Nordenskiöldii* was altogether dominant, and on the September 5th, great quantities of *Chaetoceras furcellatum* were found. After this, the quantity of plankton decreased very rapidly; the volume of the plankton sample which on the September 5th was 170 cc. had by the October 2nd dropped to 0.7 cc.; diatoms were met with throughout the whole year, with a minimum in February. In winter, mostly oceanic species were found. Ceratia, mainly *C. arcticum*, had their maximum in October and minimum in March—July. Vanhöffen made his collections with a "medium sized plankton net after Apstein" with a diameter of 14 cm. i.e. an opening of 150 sq. cm. He filtered water columns of varying depth, from 26 m. to 190 m., but we shall hardly be far wrong in reckoning that all the phytoplankton was taken in a water column from the surface down to 20 m. depth. If we wish to arrive at

a minimum value for the number of cells per l., then we should be able to divide VANHÖFFEN's figures by 300; this gives a maximal density of 900,000 diatoms on the May 23rd, 1893; for the separate species, we get maxima as follows: 400,000 *Thalassiosira Nordenskiöldii* August 16th, 1892, close on 500,000 *Chaetoceras furcellatum* September 5th, 1893, and 860,000 "Fragilarien" i.e. *Fragilaria oceanica, F. cylindrus* and ribbon-shaped *Navicula* species taken together on the May 23rd, 1893. Ceratia amount to 46 pr. l. on the October 15th, 1892. The minimum, on July 19th, 1893, is 1 cell per 10 l. For diatoms taken all together, the minimum lies in the winter months of November—February, between 2 and 20 cells per l. These figures, as regards the diatoms, are all probably rather too low than too high; owing to reduced filtration capacity, they should perhaps be multiplied by 2; the Ceratia in October on the other hand, with the scanty total plankton, were probably filtered more or less quantitatively. From this we see that the Karajak Fjord had, all through the summer from May to September, a quantitatively very rich diatom plankton; equal to what we find in spring off the coasts of Norway. VANHÖFFEN also made plankton investigations in Davis Strait proper, both on the outward voyage, in June 1892, and on the return journey in September 1893. He made counts here to arrive at the numerical proportion between the different species, but did not attempt to determine the absolute quantity of plankton. He found great quantities of diatoms (*Fragilaria*, *Thalassiosira* and *Chaetoceras*) from May 31st off Cape Farewell along a considerable portion of the route northward to Disco Bay, but rather unevenly distributed. At 63°—64° N., the vessel was beset for several days by drift ice, and here the diatoms were dominant all the time; he writes that abundance of diatoms indicates the proximity of ice.

Ceratium arcticum he encountered for the first time off Sukkertoppen (a little beyond 65° N.) and here, for part of the route, diatoms were present in subordinate quantities. The same was noted outside Disco Bay (June 21st); farther north again, however, diatoms were again abundant right into Umanak Fjord, where the water was quite clouded by the mass of diatom plankton. Dominant species were: sometimes *Fragilaria*, at others *Chaetoceras furcellatum; Thalassiosira Nordenskiöldii*, however, was also found in great numbers all the way.

Since then, OSTENFELD (1899, 1900) has investigated a number of plankton samples from Davis Strait, collected in 1898 and 1899 from the regular service of vessels running between Iceland and Greenland. In all, 17 of his samples were taken from within our area, west of 50 degrees of Longitude and north of 60° N. Latitude. A sample from May (Nr. 479, May 11th, 1898, 62°50′ N., 54°5′ W.) contains a mixture of neritic and oceanic diatoms; *Thalassiosira gravida* and *Chaetoceras decipiens* dominant; but we find also, as we should expect at this time of year, arctic-neritic species such as *Fragilaria oceanica* and *Thalassiosira hyalina*. Five samples from June contain *Phaeocystis Pouchetii* and also the same diatoms as in May, but rather less abundant; the northernmost sample (Nr. 586, from 68°51′ N., 53°57′ W.,

June 27th, 1898) taken outside Disco Bay contained no *Phaeocystis*, but on the other hand some very small quantities of *Ceratium arcticum*.

Two samples from July 12th—13th, 1899, contained diatoms, chiefly oceanic, and a number of Peridinium species; in one, Nr. 345, from 61°40′ N. and 53°3′ W., with a surface temperature of 7°, *Rhizosolenia semispina* was dominant; this species is also found farther to the south-east.

From August 1898 three samples are recorded:—

691. 62°28′ N., 55°53′ W., August 12th, surface temperature 6.0°, oceanic peridineans, including such southerly forms as *Ceratium longipes* and *Dinophysis acuta*, some diatoms.
693. 66°1′ N., 55°17′ W., T. = 4.2°, *Ceratium arcticum* dominant; also *Peridinium depressum* and *pallidium*, with *Diplopsalis lenticula*.
695. 69°11′ N., 52°35′ W., in Disco Bay, T. = 6.3°. Peridineans, primarily *Gonyaulax spinifera*, *Protoceratium reticulatum*, *Peridinium pellucidum* and *Steinii*, *Diplopsalis lenticula*. *Ceratium arcticum* was also found, but not in great numbers.

In September, 1898, 5 samples were collected. One of them, Nr. 682, is from the southernmost part of the area, at 60°14′ N., 54°52′ W., Sept. 9th, 1898. It is oceanic in character; the species most abundant is *Ceratium longipes*, with *C. arcticum* as a subordinate form. Another sample, Nr. 678, taken September 6th outside Disco Bay at 68°46′ N., 53°16′ W., temperature 2.7°, contained diatoms, especially neritic, primarily *Thalassiosira gravida*. *Ceratium arcticum* was abundant. In the three remaining samples (680, September 7th, 1898, 587, September 26th and 588, September 29th) *Ceratium arcticum* was altogether dominant.

Finally, there is a sample, Nr. 589, from the October 5th, 1898, with a very scanty oceanic plankton.

The value of this contribution to our knowledge of the plankton of Davis Strait lies chiefly in the new information it affords as to the distribution of the individual species, reference to which will be made in the following. In addition, Ostenfeld here describes for the first time the plankton association which is characterised by the occurrence of masses of *Ceratium arcticum* then known as *C. tripos* var. *labradorica* Schütt; and he calls this association the Labradorica plankton. Its distribution ranges from 65° N. Lat. northwards to Davis Strait, where it had already been observed by Cleve.

The results of previous investigations may be summed up as follows:—

1) Along the eastern side of Davis Strait there appears, in May—June, a rich diatom plankton, especially in the vicinity of land and near drift ice. Neritic species such as *Fragilaria oceanica*, *Chaetoceras furcellatum*, and *Thalassiosira Nordenskiöldii* predominate.

2) In the north-eastern part of Davis Strait from 65° N. and up into Baffins Bay, in August—September, *Ceratium arcticum* is dominant.
3) In the Karajak Fjord there is an extremely rich diatom plankton from May to September, and as early as March the diatoms begin to collect on the underside of the ice, which covers the fjord. Dominant species in May are *Fragilaria oceanica* and other forms with ribbon-shaped colonies; in July—August *Thalassiosira Nordenskiöldii*, in September *Chaetoceras furcellatum*. The greatest volume of plankton was found in September, when *Chaetoceras furcellatum*, with its long bristles, forms a looser sediment. The greatest number of cells was found in May.
4) Comparatively southerly species such as *Rhizosolenia styliformis*, *Ceratium longipes*, *tripos*, *fusus* and *furca* may be met with in oceanic water masses especially in the open southern part at different seasons of the year, but in relatively small quantities; in winter, these species may be found right up in the Karajak Fjord.

Investigations in Davis Strait in August 1924. Fylla Bank and Lille Hellefiske Bank St. 33—39.

Water samples for quantitative plankton investigations were taken in this area from 5 stations at 20—70 nautical miles from land. Of these, St. 37, which lies nearest the shore, is somewhat poorer in plankton than the others; the salinity here was not more than 31.71 at the surface. Altogether, the plankton was quite rich in diatoms, and *Dinobryon pellucidum* was at some stations the dominant form.

Most of the diatoms are neritic species; the most abundant is *Chætoceras debile*, amounting to over 50,000 cells per l. On the southern part of the Lille Hellefiske Bank (St. 35 and 38) it has its maximum at the surface and decreases towards the deep levels; the temperature of the surface layers is here abt. 3.5°, and salinity 35 ‰ or a little less. On the Fyllas Bank, where the temperature at 1—10 m. is over 6°, *Ch. debile* had almost disappeared from the surface water, but was found in abundance at 25 m. where the temperature was 1.92°. Farther north (St. 37 and 39) it is found in smaller numbers.

Thalassiosira Nordenskiöldii and *gravida* are found at all stations, both with maximum at the coldest (St. 35); the same applies to *Nitzschia seriata*. The maxima for these species are inconsiderable in comparison with the figures recorded from the shores of Europe, but it is highly probable that there are greater numbers to be found in Greenland waters during early summer.

Maximum at St. 39, where the surface salinity is highest, 33.08—33.15 ‰, is recorded for 3 species which, from their occurrence off the coast of Norway have a somewhat higher temperature optimum than the foregoing, viz.: *Leptocylindrus danicus*, *Thalassiosira bioculata* and *Chaetoceras compressum*. The first-named has not

Fig. 2.

previously been recorded from Greenland, and I had not expected to find it there. A maximum of 4000 pr. l. is not much for this species; farther north, where water masses of the same salinity show a temperature over 5°, we find ten times that number.

The most characteristic feature of the plankton in this southern area is the occurrence of the oceanic diatom *Rhizosolenia styliformis*; its large handsome cells appear in 50 cc. samples from all stations. Farther north, it is lacking, or not present in sufficient quantity to be included in the centrifuge samples. At the two stations farthest from land, 38 and 39, we find comparatively large quantities right up to the surface, most of all at the outermost station (39). At the three remaining stations it was scarce or absent at 1—10 m., but with maximum at 25—50 m. depth. There can hardly be any doubt but that this species is carried northward with water masses of Atlantic origin and propagates in the boundary area towards the Greenland coastal current; we do not find it in any water sample of lower salinity than 32.8 $^0/_{00}$.

Section across Davis Strait from Greenland to Cumberland (Exeter Sound).

This section reveals some pronounced and interesting contrasts. The two first stations, 40 (August 8th) and 54 (August 16th) near the south side of the Store Hellefiske Bank are very much alike. We find great numbers of neritic diatoms, some of comparatively southerly character: *Leptocylindrus danicus* with up to over 50,000 cells per l. *Chaetoceras compressum*, *laciniosum*, *debile*, *diadema* and *teres*, *Rhizosolenia faeroensis*, *Thalassiosira bioculata*, *gravida* and *Nordenskiöldii*. *Chaetoceras furcellatum* is also found, but mostly as chains forming resting spores which have already sunk down into the depths. As minor constituents we find *Coscinosira polychorda*, *Lauderia glacialis* and *Eucampia groenlandica*; of more oceanic species *Chaetoceras decipiens*, *Nitzschia seriata* and *delicatissima*, *Rhizosolenia alata* and *semispina*. These two stations are richer in diatoms than any of the others from this area.

At Station 40, the quantities of diatoms are more or less even down to as far as 50 m. *Chaetoceras compressum* indeed, has its maximum here; in the case of this species it is doubtless due to the fact that its vegetation period is approaching conclusion, so that it is beginning to sink down into the depths; at Station 54, eight days later, it was found only as resting spores. But it is remarkable that we find supersaturation of oxygen and a high p_H value right down to 50 m. With such a dense plankton, it is hardly likely that the light at this depth would be powerful enough to maintain an effective assimilation; it is more probable that the surface strata at Station 40 have been crowded together.

Station 41, which in hydrographical respects constitutes a transition to the conditions found on the western side of Davis Strait, has a poor plankton; most prominent are *Ceratium arcticum*, which we find here already to the amount of 760 pr. l. at 25 m. depth, and resting spores of *Chaetoceras furcellatum* from 50 m. downwards.

On the western side, we find in the surface layers a salinity of less than 32 ‰ and temperatures below 4°. The curve for 0° lies between 25 and 50 m. depth; at 50 m., we find throughout temperatures below ÷1°.

Stations 42, 43 and 45 exhibited a plankton characterised primarily by *Ceratium arcticum* to the number of over 1000 pr. l. It is the typical "Labradorica plankton" as described by Ostenfeld. In this case, it is accompanied by a characteristic association of oceanic diatoms: *Asteromphalus heptactis*, *Chaetoceras atlanticum*, *boreale* and *decipiens* and *Coscinodiscus curvatulus*, *Rhizosolenia semispina*, *Thalassiothrix longissima*. *Chaetoceras decipiens* amounts to 1000 cells pr. l., the others are less numerous. In addition, neritic species are represented by *Thalassiosira gravida*, and *Nordenskiöldii*, *Lauderia glacialis* and *Chaetoceras furcellatum*, especially at St. 45, which lies nearest land.

In Exeter Sound (St. 44) we find the same oceanic species, also *Ceratium arcticum* and several neritic: *Achnanthes taeniata*, *Chaetoceras debile*, *pseudocrinitum*, *scolopendra* and *Wighami*, *Detonula confervacea*, *Eucampia groenlandica*, *Thalassiosira decipiens*. Harsh as this coast appears, with its ice-worn beaches, bearing never a sign of *Fucaceae*, only here and there a laminaria with long air-filled stalks reaching to the surface, it is not surprising that even up in the fjords the oceanic species should predominate; it is rather to be wondered at that the land can send down any sufficient supply of nourishment to maintain a fairly rich production. For it is extremely likely that it is the supply of nourishment from land which enables the diatoms to flourish not only up in the bay but even as far out as at St. 45; in the middle of Davis Strait (St. 42, 43 and 46) the diatoms are altogether far more rare.

From Cumberland to Disco Bay (St. 46—49).

The first station (46) belongs entirely to the same area which we have just described. *Ceratium arcticum* is altogether predominant, with the surprisingly high figure of over 3000 pr. l. from the surface down to 25 m. inclusive; it seems to assemble in somewhat greater density at this very limit, 25 m., in the boundary layer with 33 ‰ salinity. The formation of such a rich stock in the course of one summer shows that the rate of propagation for the species must be greater than we should expect from the low temperature. Assuming that by the June 1st there is 1 specimen pr. l., which by the August 13th has produced 3000, the daily production should be 9 %, without reckoning that a certain percentage must be devoured by other organisms or perish in some other way, and the temperature during this period has hardly risen beyond 3°. Under such conditions, our north-European species of the same genus would hardly have propagated at all. Outside the Romsdal Fjord, in April 1926, *Ceratium longipes* increased from 14 to 82 pr. l. in the course of 32 days, with a temperature from 6°—8°. This, reckoned

on a similar basis, gives an increment percentage of 5.7 per day. *C. tripos*, during the same period, hardly propagated to any appreciable extent (GRAN 1928).

Over towards Disco Bay, *Ceratium arcticum* decreases steadily in numbers; on the other hand, we find in towards land moderate quantities of neritic diatoms: *Chaetoceras debile*, *diadema*, *furcellatum*, *Coscinosira polychorda*, *Lauderia glacialis*, *Thalassiosira gravida* and *Nordenskiöldii*. Most of them appear to have passed their annual maximum, as they are found, sometimes with resting spores, in greater numbers at 25—50 m. than at the surface. The southerly species which we found off the coast of Greenland as far as the southern edge of the Store Hellefiske Bank (*Leptocylindrus danicus*, *Chaetoceras laciniosum*) are here altogether lacking.

On the other hand, we find here in the north a few small brown peridineans in greater numbers than otherwise in this area: *Dinophysis arctica* (up to 740 pr. l.) and *norvegica*, and *Protoceratium reticulatum* (up to 480 pr. l.).

Section across Fyllas Bank in towards land (Stations 58—62).

The outermost station (58) is altogether oceanic, with a surface temperature of 6.41° and salinity 33.78 ‰. The plankton is very poor in diatoms. *Ceratium arcticum* is here altogether lacking. Coccolithophorids are found but in small numbers.

At the remaining stations we find the same diatom plankton as already described from St. 33—39, mainly neritic species, with maximum at the innermost station (62) as illustrated by the following tables for selected species.

Chaetoceras debile.

Depth m.	Station 58	Station 59	Station 60	Station 62
1	..	17040	34360	24000
10	..	72460	88680	10080
25	..	840	1300	11720
40	..	..	140	?
50	..	..	..	320
75	..	..	..	2540

Leptocylindrus danicus.

Depth m.	Station 58	Station 59	Station 60	Station 62
1	..	4960	7560	29280
10	..	4940	6280	40400
25	..	..	..	8880
40	..	..	..	?
50	..	..	..	1880
75	..	..	..	180

Thalassiosira Nordenskiöldii.

Depth m.	Station 58	Station 59	Station 60	Station 62
1	..	520	400	19680
10	..	800	560	13080
25	..	..	..	560
40	..	..	..	?
50	..	..	..	500
75	..	..	..	120

Thalassiosira bioculata.

Depth m.	Station 58	Station 59	Station 60	Station 62
1	..	1040	3440	880
10	..	6760	12040	800
25	..	..	120	3840
40	..	..	..	?
50	..	..	..	620
75	..	..	..	..

The diatom plankton is restricted to the surface layers with salinity below 33 $^0/_{00}$. At Stations 59 and 60, the curve for 33 $^0/_{00}$ lies between 10 and 25 m. and the diatom-bearing layer is thin; at the innermost station, the boundary lies about 50 m. depth, and we find the diatoms deeper down.

In agreement with this we also find that the surface layers exhibit supersaturation with oxygen and a high p_H value down to 10 m. inclusive at Stations 59 and 60, but right down to 25 m. at Station 62.

Remarks on the Species found in Davis Strait.

1) *Eutreptia Lanowii* Steuer. Fyllas Bank, Lille Hellefiske Bank. Scarce.
2) *Dinobryon pellucidum* Levander. Along the coast of Greenland to the south side of the Store Hellefiske Bank, often altogether dominant. Recorded by Vanhöffen and Ostenfeld.
3) *Achnanthes taeniata* Grun. in our material found only at St. 45 outside Exeter Sound and only in deeper layers, showing that its vegetative period is already at an end. Doubtless widely distributed earlier in the year.
4) *Asteromphalus heptactis* Ralfs. Characteristic form of the oceanic plankton on the western side, never in great numbers, maximum 280 pr. l. Scarce at Cape Farewell (St. 64).
5) *Bacterosira fragilis* Gran. Outside Exeter Sound, scarce. Spring form, first described from Karajak Fjord (Gran 1897).

6) *Chaetoceras atlanticum* Cleve. In August 1924 characteristic of the western side of Davis Strait, with maximum (880 pr. l.) quite close into land (St. 44 and 45).
7) *Ch. boreale* Bailey. In our material with about the same distribution as the preceding species, with maximum abt. 800 pr. l. at the same stations. Observed singly also on the eastern side of the strait.
8) *Ch. boreale* Bailey f. *varians* Gran. Singly at St. 41.
9) *Ch. compressum* Lauder (*Ch. contortum* Schütt). On the eastern side with northern limit at Store Hellefiske Bank. In some places with resting spores, showing that in quantitative respects it had culminated already, in August. Maximum at St. 40 with 34000 pr. l. at 50 m. depth.
10) *Ch. convolutum* Castr. Sparsely, on the Greenland side. Maximum 1120 pr. l. at St. 62 inside Fyllas Bank.
11) *Ch. debile* Cleve. Distributed throughout the entire area; in August, commonest of all the diatoms. On the western side only a few chains scattered throughout the centrifuge samples; in Disco Bay it had already culminated in August as it was lacking at the surface. Maximum just outside Fyllas Bank (St. 59—60) with abt. 80,000 cells pr. l. at 10 m. depth. On the outer side of Lille Hellefiske Bank (St. 38) it had its maximum at 1 m. depth. with 35,000 pr. l.
12) *Ch. decipiens* Cleve. Oceanic form, scattered throughout the entire area, but never in great numbers. It occurs most regularly on the western side, with maximum 1000 pr. l. at St. 45 outside Exeter Sound. At St. 62 a maximum of 1760.
13) *Ch. diadema* (Ehr.). According to Cleve's observations, this seems to have been the commonest Chaetoceras species in his material. I have found it scattered along the coast of Greenland from St. 62 to St. 48 outside Disco Bay, but rather unevenly distributed. Maximum 10,000 pr. l. at St. 62.
14) *Ch. furcellatum* Bailey. Throughout the entire area, but mostly with resting spores showing that its growth period nears its end in August. It is probably one of the commonest species in these waters earlier in the year. Maximum abt. 50,000 resting spores pr. l. at 50—100 m. depth at St. 40—41.
15) *Ch. laciniosum* Schütt. Along the coast of Greenland, with northern limit at Store Hellefiske Bank. Maximum 15—17,000 pr. l. at St. 40.
16) *Ch. pseudocrinitum* Ostenf. Singly, in Exeter Bay and at Fyllas Bank.
17) *Ch. scolopendra* Cleve. A single chain observed in Exeter Bay 10 m. depth.
18) *Ch. sociale* Lauder. Sparsely outside Exeter Bay and in Disco Bay, with resting spores.
19) *Ch. teres* Cleve. Along the west coast of Greenland with northern limit at Store Hellefiske Bank, sparsely. Maximum at St. 62 below Fyllas Bank, 2500 cells pr. l.

20) *Ch. Wighami* Brightwell. In Exeter Sound and just outside, maximum 2680 cells pr. l.
21) *Coscinodiscus centralis* Ehr. Singly. St. 59.
22) *C. curvatulus* Grun. A comparatively small variety with small spines on the margin, outside the boundary line between the sectors. Diameter 28—48 μ. A character form in the oceanic-arctic plankton on the western side, together with *Ceratium arcticum*. Maximum 780 pr. l. at St. 45.
23) *C. lineatus* Ehr. Singly at the oceanic station 41.
24) *C. stellaris* Roper. In Exeter Bay, 10 m. sparsely.
25) *Corethron criophilum* Castr. A single specimen of this oceanic-atlantic species was found at St. 59 outside Fyllas Bank.
26) *Coscinosira polychorda* Gran. Along the coast of Greenland right to Disco Bay, scattered and sparsely. Maximum 1840 pr. l. at St. 62, 1—10 m.
27) *Detonula confervacea* Cleve. First described from this area by Cleve, probably generally distributed earlier in the year. In our material only from Exeter Sound, 10 m. depth.
28) *Detonula* sp. (?) A small diatom in short cylindrical chains, which, from the paucity of material, was not described. In samples from Exeter Bay.
29) *Fragilaria oceanica* Cleve. Doubtless commonly distributed in spring; in our material only from St. 45 outside Exeter Sound.
30) *Eucampia groenlandica* Cleve. In our material from August scattered and sparsely. Its vegetation period is doubtless already over. Maximum at St. 40.
31) *Lauderia glacialis* (Grun). Throughout the entire area, but never in great numbers. Maximum 480 pr. l. at St. 35 (Lille Hellefiske Bank).
32) *Leptocylindrus danicus* Cleve. It was unexpected to find this relatively southerly species off the coast of Greenland, and this in comparatively considerable quantities. It was found as far north as the south side of Store Hellefiske Bank (St. 40 and 54), and had its maximum here with abt. 50,000 cells pr. l.
33) *L. minimus* Gran. Distribution as the foregoing but far more sparsely. Maximum 10,000 pr. l. at St. 62.
34) *Navicula distans* (W. Smith). Singly at St. 33.
35) *N. gelida* Grun. var. This small species, which is often met with off the coasts of Norway together with neritic plankton diatoms, was observed at St. 60, sparsely.
36) *Nitzschia Closterium* W. Smith. Throughout the entire area, but always sparsely, maximum 840 pr. l. at St. 62.
37) *N. delicatissima* Cleve. Both on the eastern and western sides but very sparsely.
38) *N. seriata* Cleve. Along the coast of Greenland as far as Disco Bay, not

observed on the western side. Maximum at St. 62 below Fyllas Bank with over 6000 pr. l. at 1—10 m.

39) *Rhizosolenia alata* Brightw. This relatively southerly oceanic form was taken at 4 stations near Fyllas Bank and Lille Hellefiske Bank. Maximum 140 pr. l. at St. 54, 25 m. depth.

40) *Rh. faeröensis* Ostenf. Along the whole coast of Greenland to St. 48 outside Disco Bay, never in great numbers. Maximum 2240 pr. l. at St. 60 outside Fyllas Bank.

41) *Rh. hebetata* Bailey. Observed once, at St. 41.

42) *Rh. hebetata* Bailey, f. *semispina* Hensen. Scattered throughout the entire area, with greatest density and regularity in the oceanic plankton of the western side. Maximum 580 pr. l. at St. 44 in Exeter Sound.

43) *Rh. setigera* Brightwell. Sparsely round Fyllas Bank. Maximum 200 pr. l.

44) *Rh. styliformis* Brightwell. This handsome, oceanic-atlantic species, which seems to propagate particularly on the boundary of the atlantic water masses adjoining colder areas, was relatively abundant at a series of stations round Fyllas Bank and Lille Hellefiske Bank. In most cases it was taken chiefly a little below the surface, and belongs apparently to water masses of 33 $^{0}/_{00}$ salinity and over. In the few cases (St. 39) where it had its sole maximum near the surface, the salinity here was over 33 $^{0}/_{00}$. Maximum 780 pr. l. At two other stations, 38 and 60, 2 maxima were observed, one at the surface and another deeper down; the latter is probably the primary, the species having come in with the oceanic water masses of high salinity and only secondarily propagated in the surface layer as well.

45) *Thalassiosira bioculata* (Grun.). Along the coast of Greenland to outside Disco Bay (St. 46) in some parts quite abundant. Maximum 12,000 cells per l. at St. 60.

46) *Th. decipiens* (Grun.). Only taken on the western side, in and outside Exeter Sound, maximum 420 pr. l. at 10 m. depth in Exeter Sound.

47) *Th. gravida* Cleve. This species which Cleve first described from Davis Strait with resting spores, was found throughout the entire area, at 18 out of 20 stations. Its maximum doubtless occurs earlier in the year; in many places, it is met with in August in the deeper layers, while lacking at the surface. Maximum 4400 cells pr. l. at St. 62.

48) *Th. minima ad int.* Under this name I have noted a small species which I have not yet been able to describe. It was taken on the southernmost section with maximum at the oceanic station 58. Probably an immigrant from the south.

49) *Th. Nordenskiöldii* Cleve. Distribution as that of *Th. gravida*, but not quite so regular. Maximum approaching 20,000 cells pr. l. at St. 62.

50) *Thalassiothrix longissima* Cleve et Grunow. Oceanic, found sparsely on the western side and at Cape Farewell (St. 64).

Silicoflagellata.

51) *Distephanus speculum* (Ehr.). Sparsely, especially on the western side of the strait.

Coccolithophorida.

As most of the samples from this area were preserved in Fleming's liquid, nothing can be said as to the distribution of the species throughout the area. Quantitatively, they are doubtless of quite subordinate importance. Even at the most oceanic station (58) from which samples were preserved in sublimate, only single specimens were found.

52) *Coccolithophora pelagica* (Wallich). Singly at St. 58.

53) *Pontosphaera Huxleyi* Lohmann. As the foregoing.

Peridiniales.

54) *Ceratium arcticum* Bailey. This oceanic species has its centre of distribution in the north-western part of the area, with a maximum of over 3500 pr. l. at St. 46. On the eastern side, it decreases in numbers towards the land, and is not regularly met with south of Lille Hellefiske Bank. Singly at Cape Farewell (St. 64).

55) *C. fusus* (Ehr.).

56) *C. intermedium* Jørg.

57) *C. lineatum* (Ehr.).

58) *C. longipes* (Bail.).

59) *C. tripos* (O. F. Müll.).

All these species were taken at St. 64 at Cape Farewell, all only singly in 50 cc. samples except *C. fusus*, which was taken at 10 m. depth to the number of 240 pr. l. None of them was found in Davis Strait. Ostenfeld found *C. longipes* on the 12th August, 1898, at 62°28′ N., 55°53′ W. i.e. some distance out at sea, in a quite oceanic sample with temperature 6°. Ostenfeld also records *C. longipes* from another oceanic station, 60°14′ N., 54°52′ W., on the 9th September, 1898, i.e. about the latitude of Cape Farewell; here also small numbers (rr) of *C. fusus* were found. This species was also found by him very sparsely in a net haul from 64°33′ N. 54°25′ W. on the 12th July, 1899, i.e. near Fyllas Bank together with oceanic species, with a surface temperature of 5.9°.

60) *Dinophysis acuminata* Clap. et Lachm. Sparsely at Fyllas Bank and Cape Farewell.

61) *D. acuta* Ehr. Oceanic-atlantic, found at Cape Farewell, but not in Davis Strait. Ostenfeld records it from Disco Bay but does not note *D. norvegica*. The two species were then not kept so strictly apart, so we may take it that his observation really applies to *D. norvegica*.

62) *D. arctica* Mereschkowsky. Throughout the entire area, especially on the western side and outside Disco Bay. It has a maximum here, of 740 pr. l. at St. 48.
63) *D. norvegica* Clap. et Lachm. Along the coast of Greenland as far as Disco Bay, never in great numbers.
64) *Diplopsalis lenticula* Bergh. Along the coast of Greenland, sparsely.
65) *Gonyaulax spinifera* (Clap. et Lachm.). Found at Cape Farewell (St. 64).
66) *G. triacantha* Jørg. Outside Disco Bay and at Fyllas Bank, singly.
67) *Goniodoma Ostenfeldi* Paulsen. West coast of Greenland, sparsely as a rule. At St. 33 up to 260 pr. l.
68) *Gymnodinium Lohmanni* Paulsen. Distributed throughout the entire area, but never found in great numbers. Maximum 240 pr. l. at St. 40.
69) *G. sp.* Sparsely, on the eastern side.
70) *Minuscula bipes* (Paulsen). On the eastern side, but sparsely.
71) *M. sp.* Small brown peridineans are here included under this head. In Disco Bay up to 880 pr. l.
72) *Oxytoxum gracile* Gran. Throughout the whole area, also on the western side, at any rate as far as Store Hellefiske Bank, but never more than one or two in each sample. Rare at the surface.
73) *Peridinium achromaticum* Levand. Along the coast of Greenland as far as Disco Bay. Maximum 200 pr. l. at St. 54.
74) *P. crassipes* Kofoid. St. 38, singly.
75) *P. conicum* Gran. St. 42, singly.
76) *P. conicoides* Paulsen. St. 42, singly.
77) *P. depressum* Bailey. Scattered throughout the whole area, most regularly on the western side, with maximum of 120 pr. l. at St. 42.
78) *P. divergens* (Ehr.). Singly at Lille Hellefiske Bank.
79) *P. geminum* Jørgensen. Sparsely, at St. 40.
80) *P. ovatum* Pouchet. Scattered along the coast of Greenland as far as Disco Bay, maximum abt. 100 pr. l.
81) *P. pallidum* Ostenf. Scattered and sparsely throughout the whole area, also on the western side.
82) *P. pellucidum* Bergh. Off the west coast of Greenland, sparsely.
83) *P. pyriforme* Paulsen. Singly at St. 37.
84) *P. roseum* Paulsen. Singly at St. 39.
85) *P. Steinii* Jørg. Scattered along the coast of Greenland to Disco Bay.
86) *P. sp.* Throughout the whole area, small peridinium species were found which could not be determined with certainty in the counting.
87) *Phalacroma rotundatum* (Clap. et Lachm.). Sparsely off the coast of Greenland.
88) *Pouchetia* sp. Especially on the western side. In Exeter Sound up to 100 pr. l.
89) *Protoceratium reticulatum* Bergh. Coast of Greenland. In Disco Bay with a

maximum of 480 pr. l. Also observed here by Ostenfeld August 16th, 1898.

90) *Torodinium robustum* Kofoid. Apparently distributed throughout the whole area; only singly in all samples.

91) *T. teredo* (Pouchet). Found at St. 54.

Infusoria.

92) *Cyttarocylis denticulata* (Ehr.). Throughout the whole area, up to 120 pr. l. but as a rule singly in the 50 cc. samples.

93) *C. norvegica* (Clap. et Lachm.). As the foregoing but hardly quite so regular.

94) *Laboea acuminata* Leegaard. Sparsely along the coast of Greenland. Maximum at St. 40 (up to 80 pr. l.).

95) *L. conica* Lohmann. At all stations except the oceanic-atlantic St. 58, mainly at the surface; maximum 940 pr. l. at the decidedly arctic St. 45; but also abundant on the eastern side, with a maximum of 740 pr. l. at Lille Hellefiske Bank St. 38.

96) *L. constricta* (Meunier). Scattered throughout the whole area, not so abundant as the previous species and for the most part rather deeper down.

97) *L. crassula* Leegaard. As the previous sp. but even less common.

98) *L. emergens* Leegaard. Commoner than the two previous species found mostly in the colder waters on the western side. At St. 45 a maximum of 780 pr. l. Two species are probably comprised unter this name.

99) *L. pulchra* Leegaard. Singly at St. 37.

100) *L. reticulata* Leegaard. Quite abundant round Fyllas Bank and Lille Hellefiske Bank, up to 1200 pr. l. at St. 38.

101) *L. strobila* Lohmann. Throughout the whole area save at the northernmost stations round Disco Bay; not so abundant as *L. conica*. Maximum up to 180 pr. l. in Exeter Sound and just outside.

102) *L. vestita* Leegaard. Throughout the whole area. Maximum of a little over 400 pr. l. in and near Exeter Sound.

103) *L. sp.* A large and characteristic species, like *L. conica* in shape, but with more powerful *cilia*, was found scattered throughout the entire area, with maximum of 200 pr. l. at St. 54.

104) *Leprotintinnus pellucidus* (Cleve). Sparsely outside Disco Bay at St. 47—48.

105) *Lohmaniella oviformis* Leegaard. Scattered throughout the whole area, but never in great numbers. Maximum at the southernmost stations, with up to 440 pr. l. at St. 60.

106) *L. spiralis* Leegaard. Throughout the whole area as the previous species, but far less common. Maximum 180 pr. l. at St. 38.

107) *Mesodinium rubrum* Lohmann. Throughout the whole area, but rather unevenly distributed. Maxima at St. 38 (1420 pr. l.), in Disco Bay (760 pr. l.)

and in Exeter Sound (660 pr. l.) where it appears to shun the surface layers with low salinity. The specimens found here were exceptionally small, with few cilia, whether a distinct species or a juvenile form of the larger type with its exceedingly dense border of cilia, which is otherwise common. The species seems to be decidedly neritic.

108) *Ptychocylis urnula* (Clap. et Lachm.). Singly in the centrifuge samples both on the eastern and western side. Always *f. obtusa* except at the oceanic-atlantic St. 58, where *f. acuta* was observed.

109) *Strombidium acutum* Leegaard was observed at St. 49 in Disco Bay.

110) *Tintinnus acuminatus* Clap. et Lachm. Singly at St. 38—39 and off Cape Farewell (St. 64).

111) *Infusoria indeterminata.* Scattered throughout the area were found a few species probably not yet described and which could not be subjected to closer investigation on the voyage. These forms, however, play as a rule but a quite subordinate part.

Radiolaria.

112) *Protocystis tridens* Häckel was taken at 50—75 m. at the oceanic-atlantic St. 58.

Rotatoria.

113) *Synchaeta triophthalma* Lauterborn. This characteristic species is so common along the coast of Greenland that it was observed quite regularly even in the centrifuge samples, at St. 62 at 10 m. amounting to no less than 240 pr. l.

Copepoda.

114) *Microsetella norvegica* (Boeck). In and outside Disco Bay this species was so common that it was observed in the centrifuge samples. Its characteristic *nauplii* were also found at the same place.

115) *Oithona similis* Claus. Throughout the whole area, singly in the centrifuge samples.

116) *Nauplii*, doubtless mainly of *Oithona*, were found at nearly all stations. Maximum 140 pr. l. at St. 38.

Appendicularia.

117) *Fritillaria borealis* Lohmann was observed at 6 stations along the coast of Greenland as far as Store Hellefiske Bank. At St. 54 no less than 120 pr. l.

Summary of Results.

On the "Michael Sars" Expedition in 1924, plankton samples were collected chiefly from two areas, the Norwegian Sea and Davis Strait.

. The Norwegian Sea.

The southern part of the Norwegian Sea was investigated both in July and on the return voyage during the first few days of September; it was not to be expected, however, that two such sections should suffice to give more than a preliminary orientation as to the conditions of production in summer.

We know from previous investigations (Hjort & Gran 1900, Gran 1902, Gran 1915) and from the mass of material published in tabular form in the Bulletin Trimestriel for the years 1901—1908 by the Conseil Permanent International pour l'Exploration de la Mer, that in May, dense clouds of diatoms regularly make their appearance north of Scotland, north of the Faeroes and up towards the ice in the direction of Jan Mayen in the northern bottlenose field. It is extremely likely that this occurrence is physiologically determined on the one hand by the supply of nourishment from Scotland and the Faeroes, on the other by the melting of the polar ice. It is still a question whether the importance of the polar ice lies in its containing a latent store of food stuffs from the rivers of Siberia, or whether, in course of melting, it may also help to produce vertical circulation.

But in summer, at any rate in the southern part of the Norwegian Sea, the diatoms are, quantitatively speaking, of quite subordinate importance. The same applies to the second group, the Ceratia, which in summer make up the greater part of the production along the coasts of Norway; even in September, when we should expect to find their annual maximum in these latitudes, the quantities found were altogether insignificant compared with those observed in the Skagerak and along the Norwegian shores of the North Sea and Arctic Ocean. We may then, probably, take it that the Ceratia, though, as oceanic organisms, they are distributed throughout the whole of the Norwegian Sea all the year round, nevertheless have their quantitative centre of distribution along the coasts of northern Europe, with the exception of *C. arcticum*, which in the Norwegian Sea has its centre of distribution north of Iceland. The remaining species flow out with the surface water from the Norwegian coastal waters and from the North Sea, as was already distinctly apparent on the first cruise of the "Michael Sars" in 1900 (Hjort 1901). Quantitatively speaking, it is doubtless incorrect to assume, as for instance Jörgensen (1912), that they are carried into the Norwegian Sea from the Atlantic via the Faeroe-Shetland Channel.

As observed by Wulff (1916, 1927) in the Barents Sea, wide areas are in summer dominated by the nannoplankton organisms; in the warmest parts, with salinity at the surface over 35 $^{0}/_{00}$, *Pontosphaera Huxleyi* predominates; in other parts flagellates and minor forms not yet classified in detail. Their total volume and weight do not amount to values comparable with those of the diatoms, but they may nevertheless be comparatively effective as producers, owing to their relatively extensive surface, occasioning a proportionately active metabolism. According to Krohn-Nielsen's analyses, the surface layers exhibit so great a

surplus of oxygen from the surface down to abt. 50 m. depth as to suggest a lively production. The next thing to be done is to ascertain the importance of these smallest organisms in the metabolism of the sea. This cannot be done save by following the development within a restricted area throughout a whole season, and under conditions sufficiently favourable to permit the treatment of a large amount of material as far as possible in a fresh state, the chemical side of the question being dealt with at the same time by all-round investigations.

Davis Strait.

As Vanhöffen and Cleve have shown, the plankton development in Davis Strait and in a Greenland fjord such as the Karajak Fjord commences in May with a rich development of arctic-neritic diatoms, among which *Fragilaria oceanica* and other species with ribbon-shaped colonies play a notable part. This production is particularly great in the fjords and round the melting drift ice. It is paralleled by the mass development of diatoms observed for instance off the coast of Norway in March and April, and in the Gulf of St. Lawrence in May (Gran 1919) or perhaps somewhat earlier; the specific constitution of the association forming the first crop of the spring is characteristic of each locality.

In August, there were only the remains of these communities to be found; in Exeter Sound, where great icebergs were still observed, and the salinity at the surface was not more than 20 $^{0}/_{00}$ owing to the melting of the ice, several of the characteristic species were met with but none in great numbers. The fjord inside is extremely barren; great stretches were devoid of all vegetation as regards the higher plant forms. There cannot here be any essential supply of nourishment to the fjord from the land, and the ice formed on the spot can likewise hardly contain any great amount of nutritive salts. It is not surprising therefore that the plankton, in point of quantity, will not bear comparison with the dense masses found by Vanhöffen in the Karajak Fjord all through the summer.

On the eastern side of Davis Strait, along the coast of Greenland from Fyllas Bank to the Store Hellefiske Bank, a neritic plankton was found, with quantities of *Dinobryon pellucidum* and an association of diatoms composed of many different species, which, from their occurrence on the shores of Europe appear to have a comparatively high temperature optimum. *Leptocylindrus danicus*, *Chaetoceras debile*, *compressum* and *laciniosum* were observed in quite large quantities, *Chaetoceras teres*, *Rhizosolenia faeroensis* and *Thalassiosira bioculata* somewhat more sparsely. It is altogether surprising to find these southern forms in such rich development, even though most of the species were also observed in Davis Strait during the previous expeditions. Most astonishing of all was the finding of *Leptocylindrus danicus*, which has its maximum on the coast of Norway in May—June. Probably, the diatom plankton here, on the banks off the west coast of Greenland, maintained its existence ever since June, the dominant species relieving one another in this

order: *Fragilaria*, *Thalassiosira*, *Leptocylindrus*, corresponding to the succession observed in the Skagerak in March—May: *Skeletonema*, *Thalassiosira*, *Chaetoceras constrictum*, *Leptocylindrus*. In comparison with the associations met with in northern Europe, it is most surprising that *Skeletonema costatum* is altogether lacking on the west coast of Greenland, as also *Thalassiothrix nitzschioides*. It is less remarkable that *Chaetoceras constrictum* and *curvisetum* should be absent; the latter is noted by Cleve as occurring outside Disco Bay, but this is doubtless in error for *Ch. debile*; in 1896, not even Cleve was altogether certain as to the difference between these two species.

The surface layers carrying this comparatively southerly diatom plankton — it may be designated as a Leptocylindrus association — shows a temperature from 3° to a little over 5°, and salinity from 32 to 33 ‰, rarely outside these limits. Below these water layers we find as a rule colder water masses; at a single station (59) they rest immediately on water of high temperature and salinity originating from the branch of the atlantic current which flows deep down along the coast of Greenland. There can be no doubt but that the diatom-bearing surface layers are composed of Greenland coastal water, and it is extremely likely that the diatoms come from the fjords of southwest Greenland; this can be ascertained definitely when the summer plankton of these fjords is investigated. Meantime it seems likely that they have, like the Karajak Fjord, a rich diatom plankton in summer, and we can with equal certainty divine that their surface layers will in summer move outwards, when heated so as to reduce their specific gravity.

A marked contrast to this plankton is the oceanic "Labradorica plankton" found in the north-western part of the area, at St. 42, 43, 45 and 46. Besides *Ceratium arcticum* it consists of the oceanic diatoms *Chaetoceras atlanticum*, *boreale* and *decipiens*, *Asteromphalus heptactis* and *Coscinodiscus curvatulus*, all these, however, in subordinate quantities. The association has been described by Ostenfeld from the same area, and Cleve (1896) and Aurivillius (1896) both mention the rich Ceratium plankton which they found right up to the north-western part of Baffins Bay. Aurivillius found *Ceratium arcticum* between $64^1/_2$ and 79° N. Lat. and $54^1/_2$ and 80° W. Long.

The area where *Ceratium arcticum* was dominant in 1924 showed a surface temperature of 1—3° or a little over, and salinity 30—32 ‰. Below these surface layers was water with a temperature below 0° and salinity over 33, except just at Cumberland where the ice-cold water layers showed a somewhat lower salinity. According to the observations available it must be presumed that a corresponding association is regularly met with in August—September throughout a large unbroken area from the northern part of Davis Strait abt. 65° N. to the northern part of Baffins Bay, chiefly along the western side. The association is altogether oceanic in character as regards its component species; the quantities found, however, in our samples up to 3000 *Ceratium arcticum* pr. l. and over, are far greater than

generally met with under purely oceanic conditions, as for instance in the Norwegian Sea. The occurrence may best be compared with that observed in summer along the coast of Norway, or perhaps rather on the Newfoundland Bank (Gran 1912, p. 357) or in the Gulf of St. Lawrence (Gran 1919) or the Gulf of Maine (Bigelow 1926). In all these waters, a Ceratium association follows on a rich neritic diatom plankton. I have endeavoured to show (Gran 1928) that the mass development of diatoms ceases, and the Ceratia begin to predominate, as soon as the surface layers of low salinity are sufficiently heated to preclude any mixture with the deeper water by vertical circulation, while at the same time the surface layers do not obtain any abundant supply of nourishment from land or through the melting of drift ice.

This association, then, is physiologically an intermediate stage between the specifically and individually rich neritic diatom associations on the one hand and the purely oceanic plankton on the other. The Ceratium species are undoubtedly more easily satisfied in regard to nutritive salts than the neritic diatoms, but in order to develop in such great quantities as here found they must nevertheless have more food material than is generally to be obtained under purely oceanic conditions. In the present case the most important source of nourishment is probably the melting of the ice; and that such melting has recently taken place is suggested not only by the low temperature and salinity but also by the ice-diatoms which Cleve found drifting about among the ceratia in the northern part of Baffins Bay. Cleve found precisely the same species as the Vega Expedition has collected on ice floes near Cape Wankarema in Siberia; and it seems natural then to suppose that the western ice of Baffins Bay and Davis Strait has some connection with the ice masses which drift across the Polar Sea from the coastal waters of Siberia. Should this theory of Cleve's be correct, we can well understand that the drift ice carries with it nutritive salts which are released when it melts. But we do not yet know sufficient as to the distribution of the ice diatoms to regard the theory as proved. The diatoms which have grown up on the underside of the drift ice may also be of local origin, like the diatoms on the underside of the fjord ice in the Karajak Fjord observed by Vanhöffen (1897) in March 1893.

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Tabel 1. 1924. St. 33. August 4th. 63°55′ N. Lat. 53°0′ W. Long.

Depth	1	10	25	50	60
Temperature	6.10	6.21	1.92	1.17	1.41
Salinity	32.16	32.17	33.00	33.43	33.57
σ_t	25.32	25.32	26.40	26.80	26.89
Oxygen, cc pr. l.	8.13	8.36	7.81	7.63	7.80
— saturation %	116	119	101	98	100
P_H	8.26	8.23	8.14	8.08	8.04
Number of cc counted	50	50	50	50	50
Chaetoceras compressum	..	..	300	..	..
— debile	..	200	54680	..	..
— diadema	260	840	2460	..	..
Lauderia glacialis	..	..	80	..	..
Leptocylindrus danicus	..	40	140	..	..
Navicula distans	..	..	..	..	20
Nitzschia seriata	..	20	40	40	20
Rhizosolenia faeroensis	..	..	20	..	..
— setigera	..	20	..	..	..
— styliformis	..	..	240	200	360
Thalassiosira bioculata	..	..	800	..	..
— gravida	..	..	420	..	..
— Nordenskiöldii	..	20	240	..	20
Dinophysis arctica	..	40	..	..	..
— norvegica	20	..	..	..	..
Goniodoma Ostenfeldi	200	260	..	..	..
Gymnodinium Lohmanni	80	20	140	..	..
Minuscula sp.	..	20	..	..	..
Peridinium achromaticum	60	40	..	..	..
— depressum	..	20	..	..	..
— ovatum	..	40	..	..	..
— pallidum	20	..	20	..	..
— pellucidum	40	20	..	..	..
— sp.	..	40	..	..	..
Cyttarocylis denticulata	..	80	..	..	..
Laboea conica	140	60	60	..	..
— constricta	..	..	20	..	..
— crassula	20	..	20	..	..
— reticulata	300	220	..	..	..
— strobila	60	..	60	..	..
— vestita	40	40	..	..	..
— sp.	80	60	..	..	..
Lohmanniella spiralis	20	20	..	..	20
Mesodinium rubrum	160	180	80	..	..
Infusoria indeterminata	80	100	100	..	..
Synchaeta triophthalma	..	20	..	..	..
Oithona similis	..	20	..	..	..
Nauplii	..	60	..	..	..

Tabel 2. 1925. St. 35. August 6th. 64°35′ N. Lat. 53°20′ W. Long.

Depth	1	10	25	40
Temperature	3.66	3.34	3.39	2.66
Salinity	32.57	32.57	33.00	33.12
σ_t	25.91	25.94	26.27	26.43
Oxygen, cc pr. l.	7.83	7.64	7.60	7.57
— saturation %	106	103	102	100
P_H	8.16	8.14	8.12	8.00
Number of cc counted	25	50	50	50
Dinobryon pellucidum	cc	cc	420	..
Diatoms:				
Chaetoceras debile	17880	10100	720	140
— decipiens	..	160	..	..
— diadema	6400	5120	..	..
— furcellatum[1])	..	40	..	..
— laciniosum	1360	340	..	..
— teres	280	..	..	..
Coscinosira polychorda	80	100	..	..
Lauderia glacialis	80	480	20	..
Leptocylindrus danicus	2480	1380	120	..
Nitzschia seriata	1600	1300	220	..
Rhizosolenia faeroensis	..	140	20	20
— semispina	20	50	10	..
— styliformis	..	..	930	90
Thalassiosira bioculata	160	480	..	100
— gravida	2800	1040	120	20
— Nordenskiöldii	520	1260	220	60
Cilioflagellata				
Ceratium arcticum	..	..	20	..
Dinophysis norvegica	40	160	20	..
Gymnodinium Lohmanni	160	140	..	40
Peridinium ovatum	..	40	20	..
— pellucidum	80	60	80	..
— sp.	160	220	100	60
Phalacroma rotundatum	..	..	40	20
Protoceratium reticulatum	80	..	..	..
Infusoria:				
Cyttarocylis denticulata	40	40	40	..
— norvegica	..	..	20	..
Laboea conica	..	40	20	..
— constricta	40	20	40	..
— reticulata	..	60	20	..
— vestita	40	20	..	..
Mesodinium rubrum	..	180	..	..
Ptychocylis urnula	..	40	..	..
Infusoria indeterminata	40	60	20	20
Synchaeta triophthalma	..	40	..	..
Nauplii	..	20	60	..
Oithona	..	..	20	..
Fritillaria	40	..	..	..

[1]) with spores.

Tabel 3. 1924. St. 37. August 6th. 64°53′ N. Lat. 52°55′ W. Long.

Depth	1	10	25	50	75	100
Temperature	4.55	4.57	3.03	2.31	1.52	1.56
Salinity	31.71	32.54	32.54	32.88	33.06	33.26
σ_t	25.13	25.80	25.94	26.27	26.47	26.63
Oxygen, cc pr. l.	7.58	7.66	7.81	7.74	7.69	7.60
— saturation %	104	105	104	101	99	98
P_H	8.20	8.20	8.18	8.16	8.10	..
Number of cc counted	50	50	50	50	50	50
Asteromphalus heptactis	20	..	..	..	..	..
Chaetoceras debile	..	..	..	..	160	..
— laciniosum	..	80	..	..	..	..
Coscinosira polychorda	..	60	..	40	..	..
Lauderia glacialis	..	20	..	..	..	..
Nitzschia seriata	20	20	20	20	..	20
Rhizosolenia faeroensis	..	20	..	20	60	..
— semispina	40	40	20	20	30	..
— styliformis	40	40	..	200	..	..
Thalassiosira bioculata	..	..	340	..	40	..
— gravida	40	60	40	20	..	..
— Nordenskiöldii	40	..	..	..	..	..
Dinophysis norvegica	20	..	120	..	..	..
Diplopsalis lenticula	..	..	100	20	..	..
Goniodoma Ostenfeldi	60	..	..	60	..	..
Gymnodinium Lohmanni	40	20	40	..	20	..
Peridinium achromaticum	20	60	..	..	..	..
— depressum	..	..	40	..	..	..
— divergens	..	20	..	..	..	..
— ovatum	20	40	..	20	..	..
— pellucidum	20	20	..	20	..	..
— pyriforme	20	..	..	..	..	..
— sp.	20	100	120	20	..	..
Protoceratium reticulatum	20	..	20	..	..	..
Oxytoxum gracile	..	20	..	..	..	..
Cyttarocylis denticulata	..	60	40	..	..	..
— norvegica	20	..	20	20	..	..
Laboea conica	120	80	40	..	..	..
— pulchra	20	..	..	..	..	..
— reticulata	..	..	20	..	..	..
— vestita	..	..	..	20	..	..
Lohmanniella oviformis	..	..	..	..	..	20
Mesodinium rubrum	100	180	..	..	..	..
Ptychocylis urnula	..	..	20	..	20	..
Infusoria indeterminata	..	..	40	20	..	..
Synchaeta triophthalma	60	60	40	..	..	..

Tabel 4. 1924. St. 38. August 7th. 64°33′ N. Lat. 54°35′ W. Long.

Depth	1	10	25	50	75	100
Temperature	3.73	3.66	3.60	2.03	—0.44	2.31
Salinity	32.86	33.06	33.10	33.58	33.78	34.01
σ_t	26.15	26.30	26.33	26.86	27.17	27.18
Oxygen, cc pr. l.	7,96	7,94	7.55	7.48	7.85	..
— saturation %	108	108	102	98	96	..
P_H	8.17	8.16	8.11	8.07	8.07	8.03
Number of cc counted	50	50	50	50	50	50
Diatoms:						
Chaetoceras debile	35440	21120	3520	80	..	..
— decipiens	160	80	..	..	..	..
— furcellatum (spores)	20	40	..	..	..	..
Lauderia glacilis	120	80	..	..	..	..
Leptocylindrus danicus	40	20	100	..	..	..
Nitzschia seriata	220	280	120	..	..	..
Rhizosolenia faeroensis	40	160	260	..	..	..
— styliformis	550	380	780	480	50	..
— semispina	..	..	..	..	..	10
Thalassiosira bioculata	2940	2160	4280	..	..	760
— gravida	60	..	80	20	..	80
— Nordenskiöldii	40	80	40	20	..	..
Cilioflagellata:						
Gymnodinium Lohmanni	40	..	20	..	..	60
— sp.	20	..	..	..	..	..
Minuscula bipes	20	..	..	..	..	..
— sp.	..	..	20	..	..	20
Peridinium crassipes	..	20	..	..	..	..
— depressum	40	..	..	..	..	..
— ovatum	60	..	..	..	..	..
— sp.	240	120	80	..	..	100
Infusoria:						
Cyttarocylis denticulata	20	..	..	..	..	..
— norvegica	20	..	60	..	20	..
Laboea conica	720	340	40	20	..	60
— constricta	..	..	60	20	..	..
— crassula	120	60	140	..	..	..
— reticulata	1200	160	..	..	..	..
— strobila	60	40	..	..	..	..
— vestita	480	100	400	..	..	..
Lohmanniella oviformis	100	..	160	20	20	..
— spiralis	80	40	180	..	20	..
Mesodinium rubrum	1420	180	380	..	..	..
Tintinnus acuminatus	20	..	..	..	..	..
Infusoria indeterminata	120	60	20	..	..	..
Nauplii of Copepoda	140	20	20	..	20	..
Oithona similis	20	..	..	20	..	..
Cop. cet.	..	..	..	..	..	20

Tabel 5. 1924. St. 39. August 7th. 65°12′ N. Lat. 54°13′ W. Long.

Depth	1	10	25	50	75
Temperature	4.31	4.10	3.90	1.30	1.17
Salinity	33.08	33.15	33.15	33.42	33.55
σ_t	26.25	26.33	26.35	26.79	26.90
Oxygen, cc pr. l	7.66	7.62	7.75	7.08	7.45
— saturation %	106	104	106	91	95
P_H	8.18	8.16	8.18	8.03	8.00
Number of cc counted	50	50	50	50	50
Eutreptia Lanowii	20	..	..	..	..
Chaetoceras compressum	140	200	...	...	..
— debile	..	220	1360	880	120
— laciniosum	..	20	160	..	..
Coscinosira polychorda	..	..	20	..	..
Leptocylindrus danicus	820	4060	3960	..	..
Nitzschia Closterium	..	..	200	..	..
— seriata	120	280	880	20	..
Rhizosolenia alata	..	20	100	..	..
— faeroensis	..	240	140	..	..
— semispina	110	330	110	..	..
— styliformis	280	90	50	..	..
Thalassiosira bioculata	1980	4840	2860	760	..
— gravida	180	..	..	..	..
— Nordenskiöldii	160	..	60	80	20
Ceratium arcticum	..	..	20	..	..
Dinophysis norvegica	60	..	20	..	..
Gymnodinium Lohmanni	160	200	..	..	..
Minuscula sp.	..	160	220 ..	..	..
Oxytoxum gracile	..	40	..	..	..
Peridinium depressum	20	..	40	..	..
— divergens	40	20	..	..	..
— ovatum	20	40	20	..	..
— roseum	..	20	..	..	..
— Steinii	..	..	20	..	..
— sp.	220	20	40	..	60
Cyttarocylis denticulata	40	120	120	..	..
Laboea acuminata	..	40	..	..	..
— conica	340	440	..	..	..
— strobila	..	20	..	..	..
Mesodinium rubrum	120	340	..	..	..
Ptychocylis urnula	..	..	20	..	..
Tintinnus acuminatus	..	..	20	..	.. ..
Infusoria indeterminata	20	40	100	..	
Rotatoria	..	20	60	..	..
Oithona similis	20	..	..	..	..
Nauplii	..	20	20	..	..
Fritillaria borealis	20	40	..	..	..

Tabel 6. 1924. St. 40. August 8th. 66°30′ N. Lat. 54°15′ W. Long.

Depth	1	10	25	50	100
Temperature	5.16	4.62	4.48	3.65	0.97
Salinity	33.21	33.30	33.29	33.29	33.75
σ_t	26.26	26.39	26.40	26.48	27.07
Oxygen, cc pr. l.	7.39	7.53	7.72	7.59	7.07
— saturation %	104	105	107	103	90
P_H	8.16	8.15	8.17	8.15	8.03
Number of cc counted	25	25	25	25	50
Chaetoceras boreale	..	40	..	..	40
— compressum	10840	17640	14800	34680	1920
— convolutum	..	440	80	400	..
— debile	..	1260	3440	4880	..
— decipiens	120	580	320	640	140
— diadema	2960	10440	2840	3880	1260[1])
— furcellatum	1040	5740	9360	5440	49200[1])
— laciniosum	15840	17640	13360	15720	940
— teres	240	100	..	320	..
Coscinosira polychorda	..	160	..	..	20
Eucampia groenlandica	..	380	360	320	..
Lauderia glacialis	..	40	..	..	..
Leptocylindrus danicus	40080	52200	23640	31360	..
Nitzschia Closterium	400	500	360	280	300
— delicatissima	..	..	..	80	..
— seriata	2600	3000	3320	1440	300
Rhizosolenia alata	100	40	40	..	..
— faeroensis	280	480	720	920	40
— semispina	..	40	40	60	20
Thalassiosira bioculata	1080	1040	1440	640	..
— gravida	880	1400	2440	2400	..
— Nordenskiöldii	960	2840	2600	1000	..
Dinobryon pellucidum, colonies	40	380	40	80	..
Ceratium arcticum	80	..	120	40	..
Dinophysis arctica	..	40	..	..	..
— norvegica	..	40	80	40	..
Oxytoxum gracile	..	..	..	..	40
Gymnodinium Lohmanni	..	240	80	40	20
— sp.	..	120	..	..	..
Peridinium achromaticum	80	40	40	80	..
— depressum	..	..	40	..	..
— geminum	40	..	80	..	..
— ovatum	80	40	80	40	..
— pellucidum	..	..	..	40	..
— Steinii	..	..	80	40	..
— sp.	160	80	120	..	..
Cyttarocylis denticulata	80	40	40	160	..
Laboea acuminata	40	..	40	80	20
— conica	120	240	240	80	..
— emergens	..	..	..	40	..

[1]) with spores.

Tabel 6. 1924. St. 40 (continued).

Depth	1	10	25	50	100
Temperature	5.16	4.62	4.48	3.65	0.97
Salinity	33.21	33.30	33.29	33.29	33.75
σ_t	26.26	26.39	26.40	26.48	27.07
Oxygen, cc pr. l.	7.39	7.53	7.72	7.59	7.07
— saturation %	104	105	107	103	90
P_H	8.16	8.15	8.17	8.15	8.03
Number of cc counted	25	25	25	25	50
Laboea constricta	..	..	40	..	..
Lohmanniella oviformis	..	240	40	..	..
Ptychocylis urnula obtusa	40	..	80	..	..
Mesodinium rubrum	..	120	..	..	..
Infusoria indeterminata	..	20	40	120	..
Synchaeta triophthalma	..	..	120	80	..
Nauplii	..	80	120	..	..
Fritillaria borealis	80	80	40	..	..

Tabel 7. 1924. St. 41. August 8th. 66°0′ N. Lat. 56°15′ W. Long.

Depth	1	10	25	50	75	100
Temperature	4.80	4.73	3.56	—1.36	—1.55	—0.51
Salinity	33.13	33.24	33.33	33.60	33.73	33.80
σ_t	26.24	26.34	26.52	27.05	27.15	27.18
Oxygen, cc pr. l	7.27	7.29	7.33	7.55	7.11	7.00
— saturation %	101	102	99	90	85	85
P_H	8.17	8.18	8.18	8.00	7.97	7.98
Number of cc counted	50	100	50	50	50	50
Chaetoceras atlanticum	..	..	..	80	40	..
— boreale f. varians	..	..	..	..	80	..
— debile	..	..	..	240	..	..
— diadema	..	..	100	..	..	..
— furcellatum sp.	..	..	..	51120	720	..
Coscinodiscus lineatus	..	70	..	..	..	20
Nitzschia Closterium	..	..	..	20	20	..
— delicatissima	..	..	..	20	..	..
— seriata	200	..	20	50	..	..
Rhizosolenia faeroensis	80	10	660	..	..	..
— hebetata	..	..	..	10	..	..
— semispina	..	..	30	10	..	..
Thalassiosira gravida	..	..	..	40	..	..
Thalassiothrix longissima	..	20	..	..	..	..
Dinobryon, colonies	40	20	..	..	..	..
Distephanus speculum	..	30	..	..	..	..
Ceratium arcticum	200	370	760	..	..	..
Dinophysis arctica	20	20	40	..	..	..
Gymnodinium Lohmanni	20	..	220	20	20	..
— sp.	..	..	..	..	..	20
Peridinium achromaticum	40	30	..	..	..	..
— ovatum	60	10	..	..	..	..
— sp.	140	160	40	..	..	..
Pouchetia sp.	120	20	..	..	..	..
Cyttarocylis denticulata	..	30	..	20	..	..
— norvegica	..	20	20	..	..	..
Laboea conica	400	80	..	..	..	..
— emergens	..	..	20	20	..	..
— strobila	60	..	..	..	..	..
— vestita	240	10	..	40	..	..
— sp.	..	..	60	100	..	..
Lohmanniella oviformis	40	20	40	60	..	..
Mesodinium rubrum	20	..	80	..	..	..
Ptychocylis urnula obtusa	..	10	20	..	..	..
Synchaeta triophthalma	60	50	..	..	..	..
Nauplii	..	50	20	..	20	..

Tabel 8. 1924. St. 42. August 9th. 66°30′ N. Lat. 58°45′ W. Long.

Depth	1	10	25	40	50	75
Temperature	3.39	3.30	1.14	—1.00	—1.41	—1.45
Salinity	30.90	31.24	32.75	33.42	33.55	33.64
σ_t	24.60	24.89	26.26	26.90	27.01	27.08
Oxygen, cc pr. l	7.71	7.82	8.58	8.12	7.71	7.19
— saturation %	102	104	100	98	92	86
P_H	8.16	8.16	8.16	8.08	8.02	7.97
Number of cc counted	50	50	50	100	50	50
Asteromphalus heptactis	40	..	20	20	20	20
Chaetoceras atlanticum	60	..	40	..	..	..
— boreale	..	20	..	..	..	..
Coscinodiscus curvatulus	60	..	..	20	..	20
Nitzschia Closterium	..	..	..	..	..	20
Rhizosolenia semispina	110	60	..	10	..	..
Thalassiosira gravida	..	..	..	..	..	40
Ceratium arcticum	1560	1140	600	320	20	40
Dinophysis arctica	..	60	60	..	..	..
Peridinium conicoides	20	..	20	..	..	..
— depressum	20	120	..	..	..	..
— pallidum	20	..	..	..	..	..
— sp.	20	20	..	..	20	..
Pouchetia sp.	20	..	..	..	..	..
Torodinium robustum	..	..	40	..	..	..
Cyttarocylis denticulata	20	..	..	..	..	..
— norvegica	..	..	..	180	20	..
Laboea conica	100	..	..	..	..	..
— emergens	?	?	400	..	..	..
— strobila	20	..	..	..	..	..
— vestita	?	?	40	20	..	..
Lohmanniella oviformis	..	..	..	40	..	..
Nauplii	..	60	..	10	..	20

Tabel 9. 1924. St. 43. August 9th. 66°58′ N. Lat. 59°10′ W. Long.

Depth	1	10	25	50	75
Temperature	2.38	1.85	1.14	—1.52	—1.70
Salinity	31.44	31.65	33.03	33.10	33.30
σ_t	25.12	25.33	26.48	26.64	26.81
Oxygen, cc pr. l	8.01	..	8.57	7.90	7.60
— saturation %	104	..	109	94	90
P_H	8.16	8.15	8.07	7.98	7.98
Number of cc counted	50	100	50	50	50
Asteromphalus heptactis	120	60	140	280	..
Chaetoceras atlanticum	240	400	..	..	..
— boreale	140	..	..	..	..
Coscinodiscus curvatulus	60	120	..	..	..
Rhizosolenia semispina	30	110	..	..	..
Thalassiosira gravida	..	60	..	..	..
Thalassiothrix longissima	..	20	..	..	..
Distephanus speculum	..	20	..	..	..
Ceratium arcticum	1320	2760	..	40	20
Dinophysis arctica	20	10	..	..	..
Oxytoxum gracile	20	..	..	..	..
Peridinium depressum	80	20	..	..	..
— pallidum	20	..	..	..	..
Pouchetia sp.	40	40	..	..	..
Cyttarocylis denticulata	..	20	..	..	..
— norvegica	..	20	40	..	..
Laboea conica	100	200	..	..	..
— crassula	40	40	..	..	..
— emergens	600	80	..	..	..
— constricta	40	..	..	..	..
— strobila	..	70	..	..	..
— vestita	60	200	360	140	20
— sp.	..	..	..	40	..
Lohmanniella oviformis	..	..	20	..	..
— spiralis	20	20	..	..	..
Mesodinium rubrum	..	..	160	..	..
Oithona similis	..	10	20	..	..
Nauplii	..	10	..	..	..

Tabel 10. 1924. St. 44. August 10th. 66°27′ L. Lat. 62°35′ W. Long.

Depth	1	10	25	50	75
Temperature	2.29	1.10	—1.72	—1.25	—1.40
Salinity	20.05	30.03	31.44	32.52	32.75
σ_t	15.58	24.07	25.31	26.17	26.37
Oxygen, cc pr.	8.33	8.85	8.85	8.29	7.64
— saturation %	..	110	107	98	90
P_H	8.14	8.13	8.15	8.14	8.10
Number of cc counted	50	50	50	50	50
Asteromphalus heptactis	80	220	160	..	20
Chaetoceras atlanticum	120	260	880	380	..
— boreale	240	260	780	..	..
— decipiens	220	720	180	..	..
— furcellatum	4960	17020	440	..	..
— debile	..	..	160	..	..
— pseudocrinitum	..	220	..	..	..
— scolopendra	..	320	..	..	..
— Wighami	880	2680	..	..	..
Coscinodiscus curvatulus	140	300	60	..	20
— stellaris	..	100	..	..	..
Detonula confervacea	..	520	..	..	..
— sp.	40	900	..	..	..
Eucampia groenlandica	40	..	..	..	..
Nitzschia delicatissima	..	280	..	..	..
Rhizosolenia semispina	180	350	580	..	..
Thalassiiosira decipiens	60	420	60	..	..
— gravida	..	180	60	20	..
Thalassiothrix longissima	..	180	..	..	..
Distephanus speculum	..	40	..	..	..
Ceratium arcticum	1700	1360	60	60	40
Dinophysis arctica	..	20	..	..	..
Peridinium depressum	20	..	..	..	..
— pallidum	..	..	20	..	..
— sp.	..	40	..	..	..
Pouchetia sp.	..	100	40	..	..
Cyttarocylis denticulata	..	20	..	..	..
— norvegica	..	40	..	..	..
Laboea conica	20	240	..	..	..
— crassula	..	20	..	..	..
— emergens	20	200	40	..	..
— strobila	40	100	..	..	..
— vestita	40	420	20	20	20
Lohmanniella oviformis	40	60	180	20	20
Mesodinium rubrum f. minor	..	660	40	..	..
Oithona similis	..	..	20	..	..
Nauplii	20	20	..	..	..

Tabel 11. 1924. St. 45. August 13th. 66°21′ N. Lat. 61°5′ W. Long.

Depth	1	10	25	50	75
Temperature	1.09	0.93	0.83	—1.12	—1.55
Salinity	31.51	31.56	31.55	32.47	32.83
σ_t	25.27	25.31	25.30	26.13	26.43
Oxygen, cc pr. l.	8.40	8.50	8.54	8.34	8.18
— saturation %	105	106	107	99	97
Number of cc counted	50	50	50	50	50
Achnanthes taeniata	..	..	320	1000	120
Asteromphalus heptactis	140	180	120	80	20
Bacterosira fragilis	420	..	..	..	..
Chaetoceras atlanticum	880	360	820	100	20
— boreale	140	880	280	100	..
— debile	..	100	..	..	..
— decipiens	400	1020	560	40	..
— furcellatum	280	1160	400	..	100
— sociale	..	200	..	..	..
— Wighami	..	..	..	120	..
Detonula sp.	40	340	1280	700	140
Coscinodiscus curvatulus	160	200	780	220	40
Eucampia groenlandica	..	..	60	..	..
Fragilaria oceanica	480	120	800	1520	840
Lauderia glacialis	80	80	20	..	..
Nitzschia closterium	..	..	..	20	..
Rhizosolenia semispina	180	190	530	180	30
Thalassiosira decipiens	..	..	..	20	..
— gravida	180	600	760	540	120
— Nordenskiöldii	..	..	..	120	..
Distephanus speculum	..	20	..	20	20
Ceratium arcticum	760	1300	1080	300	40
Dinophysis arctica	20	20	20	..	..
Gymnodinium Lohmanni	..	20	..	..	..
Oxytoxum gracile	..	..	20	..	..
Peridinium depressum	60	..	20	20	..
— sp.	..	20	..	..	..
Pouchetia sp.	..	40	20	..	..
Cyttarocylis denticulata	20	..	20	..	..
— norvegica	—	..	..	20	..
Laboea conica	940	620	20	20	..
— emergens f. major	20	60	40	40	..
— — f. minor	440	780	40	120	..
— strobila	40	180	120	..	..
— vestita	40	440	40	..	..
— sp.	..	120	..	..	..
Lohmanniella oviformis	20	..	20	140	20
Mesodinium rubrum	20	480	240	20	..
Ptychocylis urnula	..	..	..	20	40
Nauplii	..	20	20	20	..

Tabel 12. 1924. St. 46. August 13th. 67°19′ N. Lat. 58°52′ W. Long.

Depth	1	10	25	50	75
Temperature	..	2.07	1.43	—1.23	—1.24
Salinity	30.75	30.74	33.10	33.49	33.64
σ_t	..	24.61	26.51	26.96	27.08
Oxygen, cc pr. l.	8.01	8.07	8.13	7.71	7.43
— saturation %	..	103	104	92	89
P_H	8.10	8.09	8.19	8.00	7.97
Number of cc counted	50	50	50	50	50
Asteromphalus heptactis	..	20	..	..	60
Chaatoceras atlanticum	..	..	..	20	..
Coscinodiscus curvatulus	..	..	60	40	20
Rhizosolenia semispina	..	50	40	20	..
Thalassiosira gravida	..	..	..	20	..
Ceratium arcticum	3120	3160	3540	100	60
Dinophysis arctica	40	40	60	20	..
Peridinium depressum	40	20	40	..	..
— pallidum	40	..	..	..	..
Pouchetia sp.	..	..	..	40	..
Torodinium robustum	..	..	..	..	20
Laboea conica	20	..	..	..	..
— emergens f. major	20	20	140	..	..
— — f. minor	..	..	..	..	60
— strobila	180	20	..	..	..
— vestita	80	60	240	..	..
Lohmanniella oviformis	20	..	..	60	20
Ptychocylis urnula	..	..	..	..	20
Nauplii	20	..	60	..	..

Tabel 13. 1924. St. 47. August 14th. 68°28′ N. Lat. 56°7′ W. Long.

Depth	1	10	25	50
Temperature	..	5.14	4.19	1.27
Salinity	33.29	33.29	33.48	33.55
σ_t	..	26.33	26.56	26.89
Oxygen, cc pr. l.	7.42	7.45	7.85	7.71
— saturation %	..	106	108	99
P_H	8.18	8.17	8.17	8.12
Number of cc counted	50	50	50	50
Diatoms:				
Thalassiosira bioculata	..	20	100	40
Cilioflagellata:				
Ceratium arcticum	200	120	1380	..
Dinophysis arctica	60	260	..	..
Diplopsalis lenticula	20	40	..	..
Gymnodinium Lohmanni	..	..	20	..
Minuscula sp.	80	20	..	..
Peridinium achromaticum	40	20	..	20
— ovatum	60	40	100	20
— Steinii	..	..	20	..
— sp.	480	240	140	40
Pouchetia sp.	60	..	..	..
Infusoria:				
Cyttarocylis denticulata	..	20	20	..
Laboea conica	..	20	..	..
— constricta	..	..	40	20
Leprotintinnus pellucidus	..	..	20	..
Mesodinium rubrum	120	60	20	..
Infusoria indeterminata	40	40	..	..
Synchaeta triophthalma	20	20	..	..
Oithona similis	20	..	20	..
Nauplii	20	..	20	..

Tabel 14. 1924. St. 48. August 14th. 68°28′ N. Lat. 54°40′ W. Long.

Depth	1	10	25	50	75
Temperature	5.30	5.12	3.02	2.08	1.20
Salinity	33.35	33.35	33.35	33.51	33.62
σ_t	26.36	26.38	26.59	26.80	26.95
Oxygen, cc pr. l.	7.67	7.63	7.62	7.60	7.99
— saturation %	108	107	102	99	102
P_H	8.18	8.17	8.07	8.02	8.03
Number of cc counted	50	50	50	50	50
Diatoms:					
Chaetoceras debile	..	..	5860	200	80
— decipiens	..	..	180	20	..
— diadema	..	..	80	..	..
— furcellatum (spores)	..	..	..	140	..
Lauderia glacialis	..	..	260	..	..
Nitzschia Closterium	..	..	..	20	20
— seriata	..	..	160	..	..
Rhizosolenia faeroensis	..	..	..	20	..
— semispina	..	..	..	30	..
Thalassiosira gravida	..	..	1160	..	..
— Nordenskiöldii	120	200	10200	..	..
Distephanus speculum	..	..	..	20	..
Ceratium arcticum	100	240	40	..	..
Dinophysis arctica	40	740	..	..	..
— norvegica	80	..	..	..	..
Goniodoma Ostenfeldii	..	..	20	..	..
Gonyaulax triacantha	20	..	..	..	..
Gymnodinium Lohmanni	..	40	..	..	..
Minuscula sp.	120	420	..	..	..
Peridinium achromaticum	20	120	..	..	..
— ovatum	80	..	20	..	..
— pallidum	60	..	..	..	..
— Steinii	40	40	..	..	..
— sp.	1000	580	160	20	..
Pouchetia sp.	20	60	..	..	..
Cyttarocylis denticulata	80	60	20	20	..
Laboea conica	40	..	..	..	..
— constricta	..	..	60	..	20
Leprotintinnus pellucidus	..	40	..	..	..
Lohmanniella oviformis	..	..	20	..	..
Mesodinium rubrum	100	180	40	..	..
Infusoria indeterminata	40	80	..	..	..
Synchaeta triophthalma	100	60	..	..	..
Microsetella norvegica	20	..	20	..	..
Nauplii Microsetellae	40	20	..	..	..
Nauplii ceteri	80	100	..	20	..

Tabel 15. 1924. St. 49. August 15th. 69°13′ N. Lat. 52°54′ W. Long.

Depth	1	10	25	50	75
Temperature	6.41	6.15	1.36	0.94	0.56
Salinity	32.20	32.45	33.15	33.57	33.66
σ_t	25.31	25.54	25.57	26.92	27.01
Oxygen, cc pr. l.	7.67	7.76	7.80	7.21	7.31
— saturation %	110	111	100	91	92
P_H	8.30	8.31	8.20	8.15	8.00
Number of cc counted	25	25	25	50	50
Chaetoceras debile	..	480	640	..	..
— sociale (spores)	..	..	..	440	60
Coscinosira polychorda	440	600	..	..	..
Nitzschia Closterium	..	40	..	20	..
— seriata	120	80	..	..	..
Thalassiosira Nordenskiöldii	..	2040	3960	640[1])	..
Ceratium arcticum	40	..	40	..	..
Dinophysis arctica	120	320	..	..	..
— norvegica	40	80	..	..	..
Gymnodinium Lohmanni	160	400	..	80	..
Minuscula sp.	600	880	..	..	..
Peridinium achromaticum	..	40	..	..	..
— sp.	80	120	80	40	..
Protoceratium reticulatum	480	360	..	..	..
Cyttarocylis norvegica	..	..	..	20	..
Laboea conica	120	40	..	..	..
— constricta	..	..	..	..	20
— emergens	..	120	..	..	..
— reticulata	..	40	..	..	..
— vestita	..	40	..	20	..
Lohmanniella oviformis	..	..	..	60	..
— spiralis	..	40	..	..	..
Strombidium acutum	..	40	..	..	..
Mesodinium rubrum	760	640	..	40	..
Synchaeta triophthalma	..	..	80	..	..
Microsetella norvegica	..	40	..	..	..
Nauplii Microsetellae	..	40	..	..	..
Nauplii ceteri	..	40	..	..	..

[1]) with spores.

Tabel 16. 1924. St. 54. August 16th. 66°30′ N. Lat. 55°5′ W. Long.

Depth	1	10	25	50	75
Temperature	5.34	5.24	4.42	1.00	1.07
Salinity	33.08	33.08	33.21	33.46	33.60
σ_t	26.14	26.15	26.34	26.82	26.94
Oxygen, cc pr. l.	7.16	7.20	7.34	7.25	6.73
— saturation %	101	101	102	92	86
P_H	..	..	..	..	..
Number of cc counted	25	25	25	50	50
Dinobryon colonies	40	240	160	20	..
Chaetoceras debile	..	..	1760	1220	..
— decipiens	..	..	..	140	..
— furcellatum (spores)	..	..	240	200	360
— compressum (spores)	..	..	800	340	940
— laciniosum	80	..	160	480	280
— teres	..	..	160	..	..
Leptocylindrus danicus	46080	48800	54480	17400	1500
— minimus	..	..	280	..	..
Nitzschia Closterium	40	..	120	80	..
— seriata	..	..	1120	1040	..
Rhizosolenia alata	..	40	140	20	..
— faeroensis	..	..	400	460	20
— semispina	120	160	60	..	..
Thalassiosira gravida	..	..	200	1660	340
— Nordenskiöldii	..	..	1360	440	220
Ceratium arcticum	40	240	300	..	..
Minuscula bipes	..	40	..	20	20
Gymnodinium Lohmanni	40	80	120	120	..
Oxytoxum gracile	..	..	..	40	20
Peridinium achromaticum	200	120	200	20	..
— depressum	..	..	20	..	..
— ovatum	80	80	120	..	..
— sp.	560	320	160	20	20
Pouchetia sp.	40	40	..	..	..
Torodinium robustum	..	..	40	..	..
— teredo	..	..	40	20	..
Cyttarocylis denticulata	..	..	80	..	..
Laboea conica	40	40	..	..	..
— emergens f. major	..	..	..	..	40
— vestita	..	..	..	..	20
— sp.	..	..	200	..	20
Lohmanniella oviformis	..	80	80	40	20
Mesodinium rubrum	..	120	160	..	..
Infusoria indeterminata	440	..	..	..	..
Synchaeta triophthalma	..	80	100	..	..
Oithona	..	40	..	..	..
Nauplii	..	80	..	..	..
Fritillaria borealis	120	40	20	..	..
— ova	..	40	..	..	60

Tabel 17. St. 58. August 18th. 63°39′ N. Lat. 55°1′ W. Long.

Depth	1	10	25	50	75
Temperature	6.41	6.31	5.63	4.20	4.12
Salinity	33.78	33.80	33.95	34.45	34.63
σ_t	26.57	26.59	26.79	27.34	27.50
Oxygen, cc pr. l	7.26	7.12	7.14	6.91	6.79
— saturation %	105	104	102	96	94
P_H	8.17	8.17	8.16	8.08	8.06
Number of cc counted	50	50	50	50	50
Coccolithophora pelagica	20	..	..	..	..
Pontosphaera Huxleyi	..	20	..	..	..
Nitzschia seriata	..	..	..	..	80
Rhizosolenia styliformis	..	..	150	..	20
Thalassiosira gravida	..	..	..	20	20
— minima	700	1020	..	..	..
Dinophysis acuminata	..	..	20	..	..
Gymnodinium Lohmanni	..	..	..	20	..
Oxytoxum gracile	..	..	..	20	..
Peridinium ovatum	..	20	..	20	..
Cyttarocylis denticulata	..	..	..	..	40
— norvegica	60	20	20	20	40
Laboea vestita	20	..	..	..	..
Lohmanniella oviformis	80	140	20	..	60
Ptychocylis urnula f. acuta	..	..	..	..	20
Protocystis tridens	..	..	..	20	20
Nauplii	60	40	..	..	20

Tabel 18. 1924. St. 59. August 18th. 63°41′ N. Lat. 54°6′ W. Long.

Depth	1	10	25	50	75
Temperature	4.57	3.26	4.13	6.43	5.50
Salinity	31.83	32.84	33.95	34.69	34.74
σ_t	25.24	25.88	26.96	27.27	27.43
Oxygen, cc pr. l	7.77	7.78	6.69	6.80	6.64
— saturation %	107	104	93	99	95
P_H	8.17	8.16	8.13	8.09	8.10
Number of cc counted	25	50	50	50	50
Dinobryon colonies	480	680	..	..	..
Chaetoceras boreale	200	..	..	..	..
— compressum	960	4140	..	..	..
— convolutum	...	80	..	..	..
— debile	17040	72460	840	..	..
— decipiens	200	140	..	..	..
— diadema	..	200	..	..	..
— furcellatum	..	920	..	..	..
— laciniosum	280	60	..	..	..
— pscudocrinitum	..	220	..	..	..
— teres	280	180	..	..	..
Corethron criophilum	..	40	..	..	..
Coscinodiscus centralis	..	..	40	..	..
Lauderia glacialis	..	80	..	..	..
Leptocylindrus danicus	4960	4940	..	..	..
— minimus	160	300	..	..	..
Nitzschia seriata	360	1280	..	..	..
— Closterium	..	20	..	..	..
Rhizosolenia faeroensis	520	220	..	..	..
— semispina	..	10	..	..	..
Thalassiosira bioculata	1040	6760	..	..	..
— minima	..	40	220	20	..
— Nordenskiöldii	520	800	..	..	..
Dinophysis acuminata	..	..	..	..	20
— rotundata	..	20	..	..	..
Gymnodinium Lohmanni	..	40	..	..	..
Peridinium depressum	..	40	..	..	..
— sp.	240	40	..	..	..
Cyttarocylis norvegica	..	20	..	..	20
Laboea conica	..	140	..	..	..
— emergens f. major	..	60	..	..	..
— vestita	..	20	20	20	..
— sp.	..	..	..	20	..
Lohmanniella oviformis	40	200	40	..	20
Infusoria indeterminata	..	..	20	..	..
Oithona	..	..	..	20	..
Nauplii of Copepoda	..	60	40	20	20

Tabel 19. 1924. St. 60. August 18th. 63°49′ N. Lat. 53°25′ W. Long.

Depth	1	10	25	40	50	75
Temperature	4.64	2.80	2.11	2.61	2.59	3.35
Salinity	31.96	32.61	33.51	..	33.82	33.98
σ_t	25.33	26.02	26.79	..	27.00	27.07
Oxygen, cc pr. l	7.83	8.12	7.26	7.11	7.01	6.99
— saturation %	108	107	95	94	93	94
P_H	8.21	8.17	8.01	7.99	7.98	7.98
Number of cc counted	25	25	50	50	50	50
Dinobryon, colonies	40	40	..	..	..	..
Chaetoceras compressum	..	3200	..	..	..	..
— convolutum	280	..	..	..	..	..
— debile	34360	88680	1300	140	..	..
— decipiens	200	..	..	..	..	..
— diadema	1440	..	..	..	..	..
— furcellatum	840	320	..	..	..	..
Coscinosira polychorda	320	80	..	40	..	..
Eucampia groenlandica	120	..	..	..	..	..
Lauderia glacialis	400	240	40	20	..	..
Leptocylindrus danicus	7560	6280	..	..	..	..
— minimus	1000	..	..	..	..	..
Navicula gelida	..	..	..	..	60	120
Nitzschia Closterium	320	80	..	..	..	..
— delicatissima	..	80	..	..	..	..
— seriata	1560	1640	..	40	..	..
Rhizosolenia faeroensis	960	2240	40	..	..	..
— setigera	..	80	..	..	..	..
— styliformis	260	40	..	170	50	..
Thalassiosira bioculata	3440	12040	120	..	..	..
— gravida	..	80	..	..	20	..
— minima	..	..	..	60	20	..
— Nordenskiöldii	400	560	..	..	..	..
Dinophysis norvegica	..	40	..	..	..	..
Gymnodinium Lohmanni	200	120	..	..	..	..
Oxytoxum gracile	..	..	..	20	..	..
Peridinium sp.	160	..	..	..	..	..
Protoceratium reticulatum	40	..	..	..	..	..
Cyttarocylis norvegica	..	80	20	..	..	..
Laboea conica	240	160	..	..	..	..
— emergens	..	40	..	..	..	20
— strobila	40	..	..	..	..	..
— vestita	320	..	..	..	..	..
Lohmanniella oviformis	440	40	40	20	..	20
— spiralis	40	40	..	20	..	..
Mesodinium rubrum	360	200	20	..	..	..
Infusoria indeterminata	..	40	..	20	..	..
Fritillaria borealis	120	..	..	..	..	..

Tabel 20. St. 62. August 19th. 63°40′ N. Lat. 52°5′ W. Long.

Depth	1	10	25	50	75
Temperature	3.12	4.78	3.71	1.93	1.60
Salinity	31.62	31.71	32.12	32.97	33.31
σ_t	25.00	25.11	25.55	26.37	26.68
Oxygen, cc pr. l.	7.58	7.35	7.72	7.42	7.24
— saturation %	105	102	104	96	93
P_H	8.19	8.20	8.16	8.08	8.08
Number of cc counted	25	25	25	50	50
Eutreptia Lanowii	..	80	..	..	..
Dinobryon, colonies	400	160	80	..	20
Chaetoceras boreale	160	..	..	..	..
— compressum	6840	240	13240	560	..
— convolutum	1120	480	520	..	..
— debile	24000	10080	11720	320	2540
— decipiens	1760	1760	..	..	..
— diadema	10760	3280	1360	..	..
— furcellatum	1960	1400	..	..	960
— laciniosum	1080	320	640	300	..
— teres	2480	880	880	..	..
— debile, spores	..	..	..	..	1120
Coscinosira polychorda	1840	1840	..	..	..
Lauderia glacialis	280	120	40	20	..
Leptocylindrus danicus	29280	40400	8880	1880	180
— minimus	4880	10400	1120	80	..
Nitzschia Closterium	240	840	80	20	..
— seriata	6080	6520	4280	2080	..
Rhizosolenia alata	120	..	80	..	..
— faeroensis	160	440	1320	20	..
— semispina	60	20	..	10	..
— setigera	60	200	80	..	..
— styliformis	..	..	100	30	..
Thalassiosira bioculata	880	800	3840	620	..
— gravida	2760	4400	..	..	20
— Nordenskiöldii	19680	13080	560	500	120
Dinophysis acuminata	..	40	..	..	..
Diplopsalis lenticula	..	40	..	..	..
Gonyaulax triacantha	..	40	..	..	..
Gymnodinium Lohmanni	40	80	80	60	..
Peridinium depressum	..	40	40	..	..
Torodinium robustum	..	40	..	..	..
Peridinium sp.	120	600	80	..	..
Laboea conica	80	440	120	..	20
— acuminata	..	40	..	..	..
— strobila	160	160	..	..	..
— vestita	..	80	..	..	..
— sp.	120	..	..	..	..
Lohmanniella oviformis	40	280	..	..	..
Mesodinium rubrum	?	420	40	..	..
Infusoria indeterminata	..	560	80	..	..
Synchaeta triophthalma	..	240	..	..	..
Fritillaria	..	80	..	..	..

Tabel 21. 1924. St. 64. August 22nd. 59°17′ N. Lat. 44°35′ W. Long.

Depth	1	10	25	50	100
Temperature	4.59	5.42	5.81	4.49	3.53
Salinity	32.90	33.46	33.66	34.00	34.49
σ_t	26.07	26.43	26.54	26.85	27.45
Oxygen, cc pr. l.	7.45	7.25	7.02	6.98	6.86
— saturation %	103	102	100	97	94
P_H	8.15	8.15	8.16	8.13	8.05
Number of cc counted	50	50	50	50	50
Asteromphalus heptactis	..	20	20	..	..
Nitzschia seriata	..	20	140	20	..
Rhizosolenia styliformis	20	..	20	..	..
Thalassiosira gravida	..	..	..	20	..
— longissima	..	..	20	..	..
Ceratium arcticum	..	20	..	..	..
— fusus	20	240	40	20	..
— intermedium	..	..	20	..	..
— lineatum	20	20	..	..	..
— longipes	20	..	..	20	..
— tripos	..	..	20	..	..
Dinophysis acuminata	..	20	..	..	..
— acuta	..	40	20	..	..
Gonyaulax spinitira	20	..	..	..	..
Minuscula sp.	..	160	40	..	..
Peridinium achromaticum	..	40	20	..	..
— depressum	..	40	20	..	..
— ovatum	..	20	..	..	..
— sp.	20	20	..	..	..
Phalacroma rotundatum	20	20	..	..	..
Cyttarocylis denticulata	..	..	60	20	..
Laboea acuminata	..	60	..	..	..
— conica	20	240	..	..	..
— constricta	..	80	40	..	..
— crassula	..	80	..	..	..
— strobila	..	80	..	..	..
— vestita	20	20	..	..	..
Lohmanniella oviformis	..	120	40	40	..
— spiralis	..	..	..	20	..
Tintinnus acuminatus	..	..	20	..	..
Oithona similis	20	..	..	..	..
Nauplii	..	60	..	..	..

INVESTIGATION OF THE PRODUCTION OF PLANKTON OUTSIDE THE ROMSDALSFJORD 1926—1927

BY

H. H. GRAN

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Introduction.

We may consider it as proved that the limiting factor in the production of plankton, both in marine and in fresh water, in the majority of cases, is the available amount of nutritive salts in solution. These are chiefly nitrogen and phosphorus compounds. The chemical methods for analysing these salts in sea water have either until recently been insufficiently accurate in proportion to the small quantities present or else the task has been so great that it seemed practically impossible to accomplish it. Such numbers of determinations were needed with regard to the variations in time and distance, that the results of these might be compared with the variations in the appearance of the plankton.

The colorimetrical methods, which have been introduced during the last few years by ATKINS (1923) for the determination of phosphates and by HARVEY (1926) for the determination of nitrate seem to prove satisfactory. ATKINS has shown how the phosphates in the surface layers of the sea have been used up by the diatoms, and MARSHALL and ORR (1927) have proved how the multiplication and diminution of the numbers of the diatoms during the whole year closely follow the variations of the content of phosphates in the surface layers of Loch Striven in Scotland[1]).

The next question to be considered is how the supply of nutritive salts in the surface layers in the various waters occurs at the different times of the year, and how the fertility in the different regions is determined by this supply.

NATHANSOHN (1906) has explained how the nutritive material must be carried from the surface layers down to the deeper waterlayers, when the algae sink, living or dead. Also he has shown that those animals which live at the expense of the algae make their way down to the deeper waterlayers, and that their dead bodies and their excrements sink into the depths. ATKINS has also directly proved that there is an increase in the phosphorus content of sea water from the surface layers, where it is sometimes found in extremely small quantities, down to the great depths of the sea.

The nutritive salts therefore in the surface layers will only be present in very small quantities, where these layers do not get a new supply either from land or from the deeper layers.

[1]) Cf. also SCHREIBER'S (1928) valuable paper, published after this was written.

Nathansohn (1910) showed that at Monaco there was an increase in the production of diatoms after a short period of wet weather. The diatoms are the first to react to the supply of the nutritive materials, as shown by the cultural experiments of Gaarder and Gran (1927). They have proved that the diatoms, even with such low temperatures as 0 to 1° C., multiply daily at a rate of 60—80 %, and at a temperature of 13 to 14° C. multiply roughly at a rate of 360 % in twentyfour hours. The *Ceratium*-species, which as well as the diatoms appear as a dominant part of the plankton, require a higher temperature to propagate. Even under such favourable conditions as the coasts of Northern Europe offer during the month of August, they do not propagate more rapidly than to increase about 30 % daily (Apstein 1910, Gran 1912).

Small brown peridinians such as *Peridinium triquetra* and *Minuscula bipes* may occur in great numbers, but mostly quite locally and their mass-development is as a rule of a short duration, so that they do not play such big part as the diatoms in the plankton production (Marshall and Orr 1927, p. 854). *Coccolithophorida* and chiefly *Pontosphaera Huxleyi*, particularly under oceanic conditions with a high temperature, may occur as the dominant species among the plankton. But we know nothing at present about their rate of multiplication and the same is the case with regard to the *Cyanophyceae*.

On the coasts of northern Europe where the conditions are best known the main vernal plankton development always begins with a mass-production of diatoms round about February—April, when the surface layers of the water are at their lowest temperature. The density of the plankton can be greater at this period than at any other time of the year; but the diatom-flowering is apt to be of short duration, as the diatoms may sink into the depths and disappear after three or four weeks. Birgithe Ruud (1926) has shown that the diatom-flowering at the Lofoten Islands begins near land, just after the melting of the snow has begun and gradually it spreads over the banks. Quite similar conditions are described from the Gulf of Maine by Bigelow (1926). The diatom-flowering begins at the western side of the Gulf where there first is a rise in the atmospheric temperature, and somewhat later it begins at the eastern side spreading gradually out across the Bank. In a later paper Birgithe Ruud Föyn (1928) compares the plankton production at the Lofoten Islands with Braadlie's (1924) observations on the content of the nitrates in the river water, which Gulelven, a river in the North of Norway, brings down to the sea at the different seasons of the year. The highest concentration of the nitrates is found during the melting of the snow.

This agrees with the opinion maintained previously by me (Gran 1923), that the first maximum abundance of plankton-diatoms along the coast of Norway is dependent on the nutritive supply which is brought by the melting snow from the land. On the west coast of Norway, near Bergen, where a great deal of the coast is made up of bare islands, the plankton production which takes place inside

the long narrow fjords seems only to depend upon the nutritive supply from the shore. A mass-production of other species occurs at the same time along the coast outside the fjords. This mass seems to come along with the current from Skagerack, where the nutritive supply from the Baltic during the breaking up of the ice in February produces an enormous plankton-development (GRAN 1927). The fact is not yet ascertained with certainty; but I intend in the near future with the kind assistance of my Swedish colleagues to make a closer investigation of the conditions.

In Finland VÄLIKANGAS (1926) has undertaken a close investigation of the plankton-development in the harbour of Helsingfors. Among other things he has ascertained that the greatest production of plankton takes place in the Bay of Tölö, where the greatest amount of sewage from the town of Helsingfors is poured out.

It is more difficult to prove with certainty the connection between the plankton-development and the supply of nutritive material from the depths of the sea. In fresh water the convection currents will lead under temperate conditions during the spring and autumn to a complete mixture of all water layers from the surface down to the bottom, and the two maximum records of the number of diatoms which are found in many lakes at these seasons are supposed to be dependent to some extent on this nourishment from the depth (cf. WHIPPLE 1899). In the sea, in any case along the coasts, such great differences in the salinity between the surface layers and the deeper layers exist, that a change in the temperature as a rule cannot produce a convection current in that volume of water to any great extent.

NATHANSOHN has pointed out that in places where the wind is blowing usually off shore the deeper waterlayers must come up to the surface and thus carry the nutritive salts up to the light where the algae can use them. He supposes that the rich fisheries at such places as the west-coast of Africa are due to the rising movement in the water layers, but the plankton-development is not yet sufficiently investigated here.

Vertical motion in the water will also occur where deep and powerful currents move towards shallow banks. At the Faroe-Bank we find the density of the seawater from the surface layers down to the bottom is evenly distributed and a correspondingly even distribution of a rich diatom-plankton. Such conditions cannot be obtained except by vertical circulation throughout the whole volume of water (GRAN 1915).

BIGELOW (1926) has shown that similar conditions prevail at Georges Bank outside the Gulf of Maine. Here he found in March a rich diatom plankton with *Chaetoceras sociale* as the most prominent species, and at the same time a rich *Thalassiosira*-plankton had begun to flower close to the shore, while in the region between the coastal zone and the Bank very little plankton were to be found. He says p.485:

"With the comparative active vertical circulation that prevails locally on the bank even in midsummers, tending to sweep any organic débris from the bottom up to the upper layers, whether in suspension or in solution, the bottom no doubt contributes a greater store of assimilable nitrogenous compounds to the overlying sea water than in the deeper parts of the gulf to the north."

Birgithe Ruud (1926) at the same time found similar conditions at the edge of the shelf outside the Lofoten Bank. These she has discussed more fully in a later and larger paper (Birgithe Ruud Föyn 1928). Simultaneously with the finding of a diatom-plankton of local arctic nature which was developing near land, Mrs. Föyn proved that a rich diatom-plankton of different species was obtained farther out on the Bank, where the deep volume of water from the Atlantic-current is pressed by the earth's rotation towards the edge of the shelf. The result of this movement is a vertical component, which causes the circulation of the water. Both in 1923 and 1926, when this region was investigated a corresponding maximum number of diatoms were found at the same place and at the same time of year. The most peculiar thing is that the maximum abundance out here is of a similar short duration to that near land. Mrs. Föyn attributes this rich production of diatoms at the edge of the shelf to the supply of nourishment from the depths by means of the vertical currents and she thinks it possible that a mixture with the polar water layers underneath the Gulf Stream may have occurred.

Marshall and Orr (1927) have made an extraordinarily valuable investigation of the yearly changes of the plankton in Loch Striven, and of their relation to the physico-chemical factors. The plankton production in this loch is exceptionally rich, and consists almost entirely of diatoms, which in the course of the year have a series of maximum and minimum numbers. The individual maximum numbers in several cases are composed of different species which succeed each other; but it also happens that a single species reappears as the different maximum numbers are attained, e. g. *Skeletonema costatum*. The diagrams demonstrate too how the diatoms at the end of each maximum-period sink into deep water. The authors also give a convincingly graphic account of how the phosphates, which each time are present in the surface layers are used up gradually either partly or entirely by the diatoms.

It is difficult to understand how a fjord like Loch Striven can have such an enormous production of plankton, because from the regions investigated up to the present time, it can be compared only with the Bay of Kiel. There is no big town near Loch Striven to produce a rich supply of nutritive material, neither is the loch surrounded by much cultivated land, for it is mostly rocky-hills. Marshall and Orr mention specially that no plankton carrying waters come into the loch from without, as is the case at Dröbak in the Oslofjord (Gran and Gaarder 1918). The density of the water is not as high in the surface layers as in the lower ones the whole year round. A convection current caused by the difference in tempera-

ture, cannot therefore occur to any greater extent. The authors imagine that the mixture of the water layers may be caused by the wind which moves them about, and they also mention the presence of a shoal of herring in the fjord as a factor of some importance from the metabolic point of view. Until recently may be too little importance has been attached to pelagic fish such as the herring in relation to the circulation. Their wanderings may not only carry nutritive material down to the deeper waterlayer, but also the reverse may occur, their secretions may enrich the surface layers with nitrogenous and phosphoric salts from deeper waterlayers where the animals have been feeding.

But even if one supposes that the available amount of nutritive salts in a fjord like Loch Striven are subjected in some way to an unusually vigorous circulation, it is difficult to explain the rich production of salts without assuming that there also is a big supply from the land. I am inclined to believe that it may be possible to prove such a supply exists.

As different as the conditions for a mass-production of plankton may be in the various oceanic waters, it is essential to collect as much material of observations as possible to understand the conditions. The difficulty is to select the starting point for our investigations, in such way, that we are able to give satisfactory results.

On the coasts of Norway in spring the great production of diatoms is a constant phenomenon, which has very definite significance from the stand point of economy of the coastal waters. Our most important fish, economically speaking, principally cod and herring, spawn during the spring, and the young fry support themselves mainly on the pelagic animals which develop at the expense of this vernal production of plankton.

The rapid development of the diatoms during the spring has been investigated previously in the Oslo-fjord by Gaarder and Gran (1927), off Bergen by Gran (1927), and at the Lofoten Islands by Birgithe Ruud Föyn (1928). At the first two places the conditions are rather complicated, but at the Lofoten Islands it is more understandable.

It may be that the most favourable region for such an investigation is outside the Romsdalsfjord, where the Gulf Stream comes nearer to the shore than any other place on the Norwegian coasts, and therefore it is comparatively easy to obtain a series of consecutive observations from absolute oceanic conditions through the coastal current into a deep fjord.

At Aukra whaling station Professor Johan Hjort has a motorboat, "Morild", in which it is possible to accomplish a cruise in a day. Observations can be taken from land out to the Gulf Stream outside Storeggen (the Great Edge), the steep slope of the coastal-bank. Professor Hjort's assistant, Mr. Johan Ruud, during 1926, in connection with his own investigations of the biology of the Copepods and the Euphausiids, has also made oceanographical observations and collected

and preserved watersamples for quantitative planktoninvestigation. This was done according to a scheme which had been planned and discussed. He has also carried out all the chlorine and oxygen determinations using WINKLER's method, and he has placed the material of his observations at my disposal. I, myself, took part in these investigations in March 1927, with my assistant Mrs. BIRGITHE RUUD FÖYN. On this occasion p_H determinations in accordance with MCCLENDON's method were carried out. Assisted by Mrs. FÖYN, I investigated the decomposed organic material in the sea-water and its oxidation by the marine bacteria. The results of this investigation will be published in the near future.

It was possible to work up a great deal of the material on the spot because Mr. RUUD and Dr. LÖVENSKJOLD have built a small bio-chemical laboratory at the whaling station, and it was placed at our disposal.

I wish to express my warmest thanks to Professor JOHAN HJORT, D. Ph., who has organised the scientific work at Aukra and given me the opportunity to take part in these investigations. I am also indebted to the whaling station and its manager, Mr. ANDREAS INGEBRIGTSEN, who so hospitably allowed me to stay at the station and use the material, and also to the Norwegian Whalers' Association, which paid the expenses of the investigation. I also wish to express my thanks to Mr. JOHAN RUUD for the excellent manner in which he has planned and prepared all the expeditions and placed all the oceanographical material at my disposal, and to his sister Mrs. FÖYN, who besides being a valuable assistant has stimulated my work with her interest during our discussion of the results. I must also express my thanks to Professor AUG. BRINKMANN (Bergen), Mr. OSCAR SUND, and Mr. GUNNAR ROLLEFSEN, who have provided me with valuable material for comparison.

Until recently little has been published about the plankton of the coastal waters outside Romsdalen. There are some results of qualitative plankton determinations from a hydrographical section from Christiansund on the 2nd of July 1895 (HJORT and GRAN 1899, Tab. I). Further plankton were collected on the 17th to 21st of July from four stations in the fjords by Aalesund and from the Bank outside that town during "Michael Sars"'s expeditions 1900—1901. From 24th to 29th of January 1901 plankton samples were also collected from the Sulenfjord (Aalesund) out to Storeggen (GRAN 1902, pp. 128 and 148).

There is also some unpublished work dealing with material, which I collected along the coasts in March 1898, and a series of fortnightly observations from Ona lighthouse 1898—1900.

For comparison with the content of our plankton samples from 1926—1927, this material is of so great an interest that I must quote an extract from the records, although all the samples were taken close to land.

For comparison I have chosen three stations from March 1898. 1) Vestnes in Romsdalen, just inside station 107, of the present investigation, in the Roms-

Tab. 1. Plankton-content of net-samples from the Romsdal coast 1898—1900.

	Vestnes $^{27}/_{3}$ 1898 Surface	Bud $^{29}/_{3}$ 1898 0—10 m.	Aukra $^{29}/_{3}$ 1898 0—15 m.	Ona $^{24}/_{3}$ 1899 0—25 m.	Ona $^{2}/_{4}$ 1900 0—25 m.
Phaeocystis Pouchetii	cc	cc	cc	+	+
Cerataulina Bergonii	r	..	r	..	..
Chaetoceras atlanticum	..	r	r	..	..
— boreale	..	..	..	+	r
— — f. varians	+	+	..	..	..
— compressum	..	..	..	..	r
— constrictum	r sp.[1])	..	..	r	..
— convolutum	..	..	..	+	..
— curvisetum	..	+	..	c	..
— debile	cc	cc	cc	ccc	cc
— decipiens	+	+	+	c	c
— diadema	+ sp.	..	+ sp.	+ sp.	cc sp.
— didymum	r	r	r	r	..
— furcellatum	r sp.	..	+	+ sp.	c sp.
— laciniosum	..	+	..	r	r
— sociale	..	+ sp.	..	+ sp.	+ sp.
— teres	..	r	r	..	c sp.
— Willei	r	..	..	+	..
Coscinodiscus concinnus	+	+	+	+	c
— radiatus	..	..	..	+	..
Coscinosira polychorda	+	..	+	+	..
Ditylum Brightwelli	r	..	..	r	..
Fragilaria oceanica	..	..	..	..	+
Lauderia borealis	r	+	+	c	..
— glacialis	r	+	+	+	+
Leptocylindrus danicus	..	r	..	..	+
Nitzschia delicatissima	..	..	..	r	..
— seriata	..	..	..	+	+
— sp. (in the Phaeocystis colonies)	c	+	+	..	..
Rhizosolenia alata	..	r	+	r	r
— semispina	..	..	..	..	+
Skeletonema costatum	+	+	..	+	+
Thalassiosira decipiens	r	..	+	+	..
— gravida	c	c	+	+	+
— hyalina	r	r	r	+	r
— Nordenskiöldii	c	c sp.	+	+	+
Thalassiothrix nitzschioides	+	+	c	+	+
Ceratium bucephalum	r	..	..	+	..
— furca	+	r	r	+	..
— fusus	+	..	r	+	r
— longipes	r	r	..	+	r
— tripos	+	..	..	+	r
Peridinium depressum	+	..	r	+	r
— ovatum	+	r	r	..	+

[1]) with resting spores.

dalsfjord (1927). 2) Bud, just outside the same station, and 3) Aukra, inside our station in the Julsound. These are grouped together in table 1. This table shows that there is great agreement between the observations from these stations and our corresponding observations in 1926 and 1927. *Phaeocystis Pouchetii* and *Chaetoceras debile* in great abundance dominated the plankton, and secondary to these we find a great number of purely arctic-neritic species, such as *Chaetoceras furcellatum* and *Thalassiosira hyalina* and even distinct southern forms such as *Chaetoceras didymum*, *Ditylum Brightwelli* and *Lauderia borealis*.

At Ona the observations began on April 9th 1898. The diatoms had then almost disappeared, and the most prominent species among the plankton were *Halosphaera viridis*, *Ceratium longipes*, *Peridinium depressum* and *ovatum* together with *Phaeocystis Pouchetii*. We found towards the end of March both in 1899 and 1900 (24th of March 1899 and 2nd of April 1900) a rich diatom plankton, as seen from the table, where the content from these samples has been put down besides the investigation from the Romsdalsfjord in 1898. Here we see that the similarity between the different years is very great. *Chaetoceras debile* is most prominent in all the years, and we also find the same subordinate components.

At Ona in 1898 the Peridinians were most dominating from April to December. To judge by the qualitative samples they reach their maximum number between August and October. *Ceratium tripos* was most dominant, but *C. longipes* was also found in great numbers in May, and later on *C. Macroceras*, *bucephalum*, *fusus* and *furca* abounded. Of the diatoms only *Rhizosolenia alata* was found in any marked degree, reaching its maximum number from June to August. This form Cleve (1896) regarded as one of the leading species in his *Tripos-plankton*. The conditions in 1900 were somewhat different for the spring maxima of diatoms lasted longer. Quoting further from my journal: "The plankton was very rich as late as the 9th of April, but on April 17th it was obviously decreasing." On May 28th we found however a new diatom maximum with *Chaetoceras constrictum* as the most dominant species. *Ch. laciniosum*, *Rhizosolenia Shrubsolei* and *styliformis* were present. We found the same plankton on June 5th and June 11th, but by this time *Chaetoceras constrictum* had begun to form resting spores and was suceeded by *Ch. compressum* which was completely dominant by June 18th. By the 25th of June the diatom-plankton was more oceanic in character with *Nitzschia delicatissima* and *Rhizosolenia styliformis* as the most prominent species. These conditions were about the same also on the 16th of July. Then the *Ceratium*-species began to increase and gain the upper hand, but besides these we also found great numbers of *Rhizosolenia alata* and *Chaetoceras compressum* through the whole of the month of August. These species had disappeared by the 10th of September, but from September 24th to October 9th we found a last diatom-maximum with *Chaetoceras compressum* as the main species whilst *Ch. didymum* and *Willei* were somewhat of secondary importance.

Whether this secondary maxima of diatoms which appeared during the summer and autumn of 1900, had developed close to land only or had spread across the Bank we do not know. As will be described below, a secondary diatom-maximum appeared in May and June 1926 close to the shore only. *Rhizosolenia alata*, which according to the observations taken in 1895, 1898, and 1900 seems to be fairly constant in July, was found in July 1895 all over the Bank and the whole way out to Storeggen. The same was the case on the 21st of July 1900, when we investigated the Bank area and the regions out to Storeggen onboard the "Michael Sars". We found a plankton where undoubtedly the *Ceratium*-species were most prominent, but where also *Rhizosolenia styliformis*, *alata* and *Shrubsolei* were quite common. On the Bank these species were taken along with *Guinardia flaccida*, *Nitzschia delicatissima* and *seriata*, and *Thalassiosira Nordenskiöldii* (Gran 1902, pp. 128—131).

According to the accounts of the earlier investigations we may consider it as definite that on the coasts of Romsdalen after the resting season during the winter months, a rich diatom flowering regularly appears during the latter half of March with *Chaetoceras debile* as the most prominent species and a whole series of other species in somewhat changeable numbers. This diatom-plankton again disappears in the middle of April. In place of that a *Ceratium*-plankton slowly develops. First of all came *C. longipes*, later on *C. tripos* and after that other species play a leading rôle. It becomes a typical *Tripos*-plankton in July according to the classification of Cleve, with *Rhizosolenia alata* as a characteristic species. It is similar to the plankton which floated in 1900 in the surface layers far out over the North Atlantic and very probably it was carried again towards land by the earth's rotation during the autumn. At this period the surface layers owing to the lower temperature attain an increased specific weight. This *Tripos*-plankton reaches its maximum from September to October as it comes near the coast, but there it decreases again during the winter months until March.

Besides this regular periodical plankton maxima, there may appear in some years, in the course of the spring and summer, several short diatom flowerings, and these have several species in common. But when there is a rise in the temperature of the water the different species gradually develop successively and dominate the area. *Chaetoceras debile*, *constrictum*, *compressum* form a series with the rising of temperature. *Chaetoceras curvisetum* could have formed the fourth part in the series, but this species requires a so high temperature, that it, outside the Romsdalsfjord, cannot compete with the other species. In the Oslofjord where it reaches a maximum figure during the summer, the temperature rises to from 18 to 20° C.

The conditions here resemble very much those observed in the Clyde Sea Area at Clapochlar in Loch Striven. At both places, the changes in the occurrence of the diatoms must be due to the quantitative changes of the content of nutritive salts in the surface waterlayers, which Marshall and Orr have proved with regard to Loch Striven.

Observations from the Cruises 1926—1927.

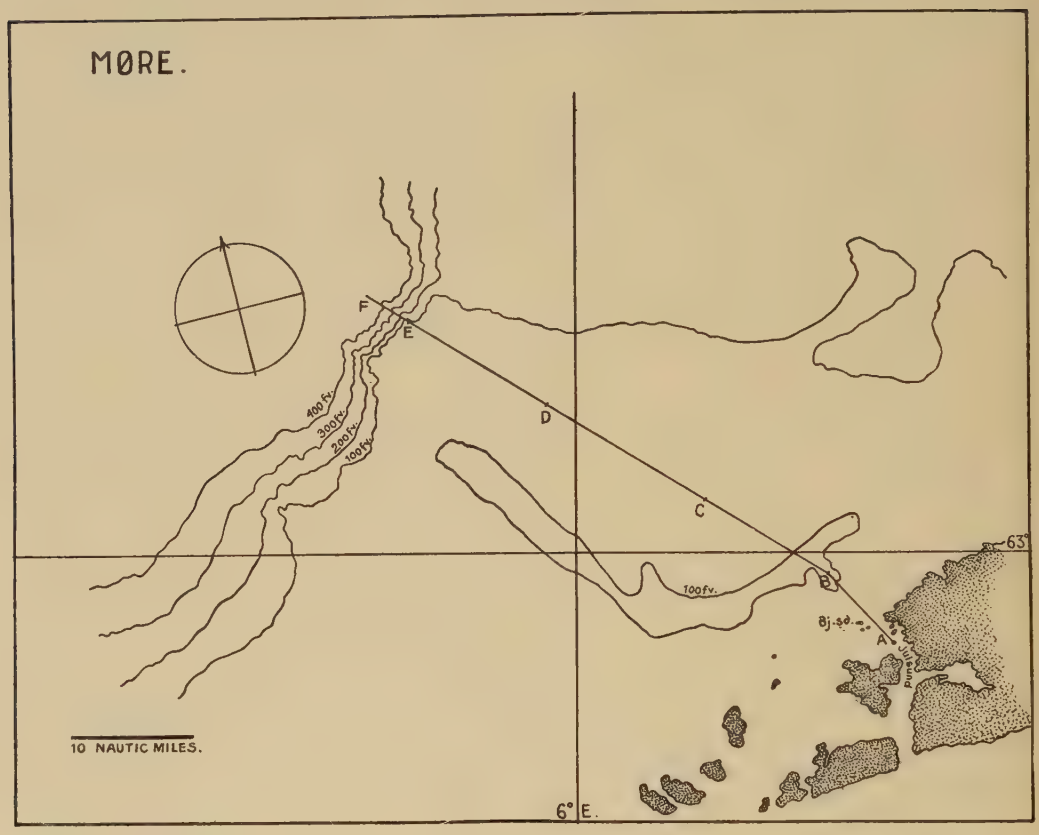

Fig. 1.

The plan for the investigations was the following: Fortnightly samples were collected at 5 fixed stations from the following depths: 1, 10, 25, 40 and 75 metres.

The following stations were chosen:

A. Insides the skerries in the Julsound, connecting the Romsdalsfjord with the open sea.
B. The Bud-deep, 5′ NNW. off Björnsund. Depth 180 metres.
C. The Bud-ground, the shallowest part of the coastal bank, 17′ NW. off Björnsund. Depth 90 metres.
D. The middle of the coastal bank, 32′ NW. off Björnsund. Depth 140 metres.
E. The edge of the bank (Storeggen), 44′ NW. off Björnsund. At some occasions observations were made also at a sixth station
F. Outside Storeggen, 50—51′ NW. off Björnsund.

First Section, 16th—18th March 1926.

Tables I—V.

It was intended to begin this investigation as early as possible to get a record of the conditions before the phyto-plankton began its main reproduction.

Owing to certain circumstances this intention was only partly carried out, for we found that the diatoms already had begun to reproduce near land. The most important species were *Skeletonema costatum* with a maximum number above 600.000 cells per litre; *Chaetoceras sociale* was flowering richly, and *Chaetoceras debile* had a maximum number above 100.000 cells per litre. Both the last species had their maximum figure in the surface layers, in water with salinity below 33 $^0/_{00}$ and a temperature below 4° C. Both of them had begun already to sink towards the deeper waterlayers so that the reproductive period must have been going on for a week or two. As secondary part of the plankton we found quite a number of species in the Julsound, e. g. *Chaetoceras compressum*, *laciniosum*, and *scolopendra*, as well as *Thalassiosira Nordenskiöldii* and *Thalassiothrix nitzschioides*. Particularly must be mentioned the rather southern form *Lauderia borealis*, which seems to be an integral part of the plankton of the Romsdalsfjord, contrary to the plankton on the banks outside. We found the arctic forms *Bacterosira fragilis* and *Eucampia groenlandica* present.

At all the other stations the plankton was still very poor. Most of the species were present in such few numbers that they were discovered singly in the centrifuged water samples of 50 cc. Most regularly spread over the whole Bank were *Skeletonema costatum* and *Thalassiosira decipiens*. The *Ceratium*-species demand a higher temperature to reproduce and were found at this period only as scattered remains of the reproduction of the summer and autumn, and just as often in the deeper waterlayers as in the surface layers, and *Ceratium fusus* was found more frequently than *C. furca* and *tripos*. From 1 to 25 metres the average number for all species put together was 28 per litre. *Ceratium arcticum* was observed at Storeggen in water of high salinity (35,16 $^0/_{00}$). Of Infusorians, already *Mesodinium* occurred in no small quantities, mostly close to land and particularly in the surface layers of the water. *Lohmanniella oviformis* was present, spread over the whole area and was to be found at every depth.

Second Section, 26th—27th March 1926.

Tables VI—IX.

The temperature and the salinity had not changed much in the ten days, but there had been a rapid increase in the number of plankton diatoms in the Julsound, and out on Storeggen. At the Bank, however, this increase had not been attained although the oxygen content had reached the point of saturation in the surface-layers.

Skeletonema costatum and *Chaetoceras debile* were still most prominent near land. *Ch. sociale* was already very much reduced in numbers and was mostly found as resting spores. Of other species there were *Chaetoceras decipiens*, *laciniosum*, and *scolopendra*, *Thalassiosira Nordenskiöldii*, and *gravida*, and *Thalassiothrix nitz-*

Tabel 2. Distribution of 4 selected species over the coastal bank 26th—27th of March 1926.

m.	Chaetoceras debile				Skeletonema costatum			
	St. 46 (F)	St. 45 (C)	St. 44 (B)	St. 43 (A)	St. 46	St. 45	St. 44	St. 43
1.....	309000	1500	7400	395500	1800	28100	112200	454250
10.....	322600	840	35200	102500	7000	23700	45700	171100
25.....	240	980	1720	106700	..	20200	5200	92000
40.....	380	..	..	?	480	58640	3520	?
75.....	..	..	..	?	920	460	1560	?

m.	Nitzschia seriata				Thalassiosira gravida			
	St. 46	St. 45	St. 44	St. 43	St. 46	St. 45	St. 44	St. 43
1.....	5600	..	..	250	30100	..	200	2750
10.....	4800	..	..	400	29100	..	..	1300
25.....	60	..	..	..	200	..	..	..
40.....	80	..	..	?	620	..	..	?
75.....	..	..	..	?	..	..	..	?

schioides. Of the southern neritic species *Lauderia borealis* was still found and of arctic forms *Fragilaria oceanica* and *Eucampia groenlandica*. The greatest numbers were found in the surface layers down to a depth of 10 metres with a temperature below 4° C. But in 25 and 40 metres, where the temperature was below 4,5° C. and the salinity below 33,5 $^{0}/_{00}$, we found quite an important number. At a depth of 75 metres, where both the temperature and the salinity were considerably higher, there was on the contrary very little to be found.

Out on Storeggen, where the plankton ten days previously had been rather scanty, we now found a very rich diatom-plankton. Here too *Chaetoceras debile* was most prominent. *Ch. laciniosum* occurred almost in similar numbers, as well as quite a series of other species, which were absent near land or occurred in much smaller numbers.

The following species were found in over 1000 cells per litre.

In the Julsound		At Storeggen	
Chaetoceras debile max.....	395500	Asterionella japonica.....	1500
— decipiens	5750	Chaetoceras boreale	1500
— laciniosum	7500	— compressum.....	7700
— scolopendra	3750	— constrictum.....	22600
— sociale (spores) ...	19900	— curvisetum.....	1900
Coscinosira polychorda	1200	— debile	322600

In the Julsound		At Storeggen	
Fragilaria oceanica	2600	Chaetoceras diadema	36800
Leptocylindrus minimus	1250	— laciniosum	201900
Nitzschia delicatissima	2500	— scolopendra	24300
Skeletonema costatum	454250	— teres	11500
Thalassiosira decipiens	1600	Leptocylindrus danicus	5100
— gravida	2750	Navicula gelida	3700
— Nordenskiöldii	3600	Nitzschia seriata	5600
Thalassiothrix nitzschioides	5500	Rhizosolenia semispina	2200
		Skeletonema costatum	7000
		Thalassiosira gravida	30100
		— Nordenskiöldii	10200

Those species, which were found in greater numbers out at Storeggen than near land, were not of more oceanic nature than those species which were most prominent near land. Some of them e. g. *Asterionella japonica*, *Chaetoceras compressum*, *constrictum*, and *curvisetum*, and *Leptocylindrus danicus* were of a more southern character. But the temperature was also over 2° C. higher out there than near land.

The production of plankton on Storeggen was evidently restricted to the surface layers to a depth of 10 metres with a salinity about 34,5 ‰ and a temperature a little above 6° C. The actual Atlantic water with a salinity above 35 ‰ and a temperature above 7° C. was much poorer. Unfortunately on this cruise we had to omit the intermediate station on the Bank inside Storeggen on account of heavy weather, and we are therefore unable to say how far inwards across the Bank this rich plankton extended. On the inner part of the Bank (stations 44 and 45) where the salinity of the surface layers was about 33,2 ‰ and the temperature a little above 4° C., a plankton occurred which in character resembled the plankton in the Julsound. There was a decrease in the number of the plankton in this region from the shore out to the Bank.

The distribution on the 26th and 27th of March resembles that on the Bank outside the Lofoten Islands in April 1923, as described by Birgithe Ruud Föyn (1928). Here too at the edge of the shelf (Vesteraalseggen) an isolated maximum of plankton was found. It was of a more southern character than the plankton association which developed close to the shore at the same time. The most prominent species were first *Skeletonema costatum*, then *Thalassiosira gravida*, *Th. Nordenskiöldii*, *Nitzschia seriata*, *N. delicatissima* and *Chaetoceras laciniosum*. The salinity of the water was 35,15 ‰ and the temperature 6,7° C. At the same place and at the same date (April 13th) similar conditions prevailed in 1926. Also that year *Skeletonema costatum* was most numerous, but besides the other above mentioned species there were several others. It must be noted specially that *Asterionella*

japonica occurred although in minor quantities. That year, the great abundance of plankton was limited to the surface layers down to a depth of 10 metres, where the salinity of the water was 34,77 $^{0}/_{00}$ and the temperature 5,3° C. The conditions at our station 46 at Storeggen in 1926 were also parallel to those of the same year described by Mrs. Föyn from Vesteraalseggen. The difference was that *Skeletonema* was most prominent at Vesteraalseggen while at Storeggen it played a secondary rôle. At Vesteraalseggen the period of development was at least two weeks later or perhaps even more judging from the state of development of the plankton.

The other parts of the plankton, the Cilioflagellates and the Infusorians, seemed on the 26th—27th of March to be the same in number as ten days previously. In the samples richest in diatoms the subordinate species were examined less thoroughly.

The determinations of oxygen showed a supersaturation in the surface layers in the Julsound and at Storeggen. At the Bank the surface layers were only saturated with oxygen.

Third Section, 9th—10th April 1926.

Tables X—XIV.

The hydrographical conditions were the same on the whole. In the Julsound the salinity had gone down a little in the surface layers and the temperature had gone up a little, particularly at the two stations farthest out.

The Phyto-plankton was very rich over the whole of the investigated area. In the Julsound the maximum had already passed. The greatest number was not found any longer in the surface layers but at a depth of about 25 metres. At other stations too, with the exception of that one farthest out, a great abundance of plankton occurred down to a depth of 40 metres inclusive. This may be due to a stowing together of the surface layers of the water, but very probably it may be attributed to the fact that the diatoms had sunk down to the deeper water layers. In all probability the development had reached its maximum over the whole area.

The species on the whole were the same as those taken two weeks previously. The limits of the two reproductive centres had merged into each other (Fig. 2). But still two marked areas could be distinguished by their characteristic plankton. One close to the shore with *Chaetoceras debile* and *Skeletonema costatum* as the most prominent species, and the other farther out where *Chaetoceras debile* also occurred but in smaller number along with the following species which here had a local maximum by this time: *Asterionella japonica*, *Chaetoceras constrictum* and *diadema*, *Navicula gelida*, *Nitzschia seriata*, *Thalassiosira gravida*, *Th. Nordenskiöldii*, and *Leptocylindrus danicus*. *Nitzschia seriata* and *Thalassiosira gravida* had their maximum at station 49, furthest out on the Bank, and the other species at station 48, at the middle of the Bank, where the mass-development of *Skeletonema costatum* had

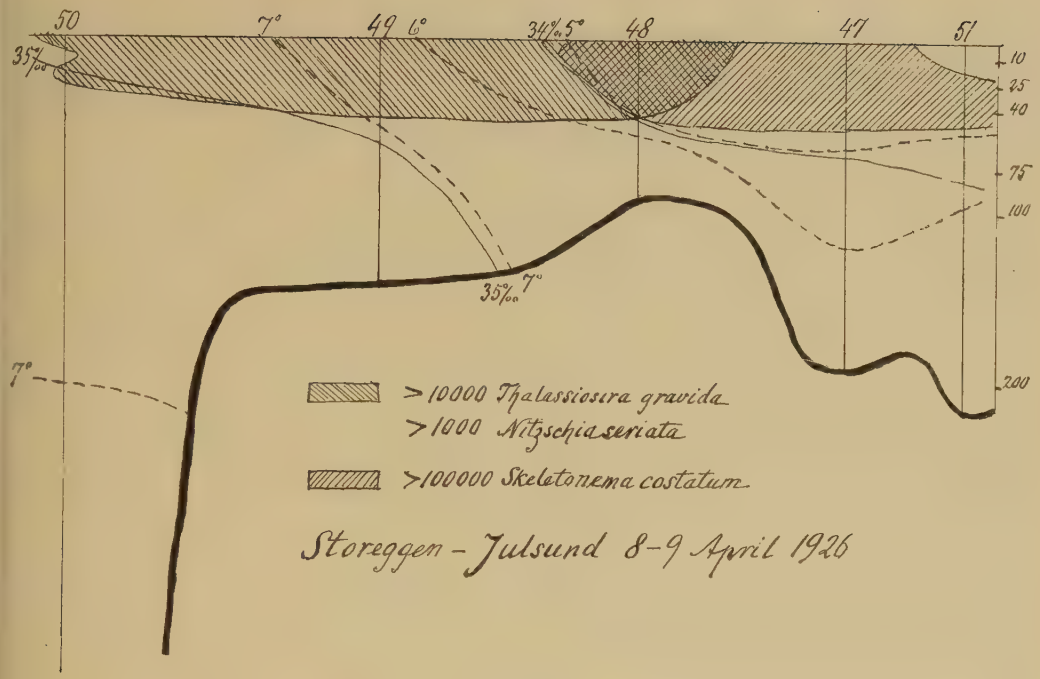

Fig. 2.

Table 3. Distribution of four selected species over the coastal bank 9th—10th of April 1926.

m.	Chaetoceras debile					Skeletonema costatum				
	St. 50 (F)	St. 49 (D)	St. 48 (C)	St. 47 (B)	St. 51 (A)	St. 50	St. 49	St. 48	St. 47	St. 51
1.....	127500	158800	187400	110600	611200	..	2000	418000	571500	12600
10.....	6760	118800	144600	81200	779600	60	..	235000	387800	59800
25.....	58500	49650	176800	?	949800	180	160	259200	?	208600
40.....	..	62300	123200	142600	776000	..	..	131000	2224800	288800
75.....	..	21540	200	4080	18040	100	500	80	5080	1760

m.	Thalassiosira gravida					Nitzschia seriata				
	St. 50	St. 49	St. 48	St. 47	St. 51	St. 50	St. 49	St. 48	St. 47	St. 51
1.....	11600	19100	14800	2600	800	3700	4200	3800	200	..
10.....	2080	18800	15600	1200	600	520	2800	3800	800	..
25.....	12400	16300	17360	?	1200	2760	3220	3160	?	200
40.....	160	12700	10500	5600	600	..	3700	1125	400	600
75.....	100	6600	160	120	240	..	980	20	20	..

mixed with them. *Chaetoceras laciniosum*, which on the 28th—29th of March occurred in very great abundance at Storeggen, had now passed its maximum reproductive stage and was only found in small quantities. Along other parts of the Norwegian coast this species forms resting spores very early and disappears from the plankton before most of the other species.

In the Julsound there still occurred some secondary species, which gave the plankton a local character. Of arctic forms there were *Achnanthes taeniata* and *Chaetoceras furcellatum* (with resting spores) and of the more southern species there was *Lauderia borealis*.

Out on Storeggen, typical oceanic species such as *Corethron criphilum*, *Coscinodiscus subbulliens*, and *Thalassiothrix longissima* occurred, and at the utmost station on the Bank (49), where the southern species at that time were centred, *Coscinodiscus centralis* and *subbulliens*, and *Rhizosolenia alata*. The rare Atlantic species *Oxytoxum diploconus* was found in the samples both from 40 metres and 75 metres.

The determination of the oxygen content of the water showed a supersaturation in the surface layers over the whole area, the highest being found at the Julsound. On the whole the oxygen content of the water was less nearer the land than out across the Bank. At Storeggen there was a rather high supersaturation in a depth of 1 metre, 106,8 %.

At the two stations nearest land (stations 51 and 47) the waterlayers were supersaturated down to a depth of 40 metres. Later on we are going to discuss if the light in this depth is sufficient to sustain the photosynthesis of the algae. The conditions might also be explained by stowing together of the surface layers of the coastal current.

Fourth Section, 28th—29th April 1926.

Tables XV—XX.

At the Julsound and on the Bank a thin surface waterlayer of lower salinity and higher temperature had been formed by this time. The rise in the temperature in the Julsound was above 3° C. At the station 67 just outside Storeggen, both the salinity and particularly the temperature were higher than at the previous examination as described in the last section. The water was of a more Atlantic character than before. The upper limit of the 35 ‰ water lay above the depth of 10 metres.

The rich abundance of diatoms had almost disappeared. At all the intermediate stations not a single diatom could be found in the samples of 50 cc. In the Julsound and out at Storeggen still some scanty remains of the same species were found, that had appeared less than three weeks previously in very great quantities. *Leptocylindrus minimus* and *Chaetoceras debile* were those found in the Julsound, and *Leptocylindrus danicus* at Storeggen. Here also small quantities of

purely oceanic species such as *Coscinodiscus excentricus* and *subbulliens*, and *Thalassiosira subtilis* were present. The *Ceratium*-species appeared evenly distributed over the whole area, but still in small numbers. All the species put together from a depth of 1 to 25 metres, formed an average of 43 cells per litre, of which 14 cells per litre were *Ceratium longipes*. In the Julsound there was an increase of *Gymnodinium Lohmanni*. *Phalacroma rotundatum* was present both in the Julsound and all over the Bank. At the four stations nearest land we found an average of 11 cells per litre in a depth of 1 to 40 metres. Great numbers of *Mesodinium* were caught in the Julsound but there was a gradual decrease out across the Bank, while *Laboea conica* and *Laboea vestita* had their maximum number out at Storeggen, 1040 and 460 cells per litre respectively.

A very great decrease in the oxygen content in the surface layers occurred at the three stations nearest land, but it was about the same as before at the stations further out. Just outside Storeggen a small increase at a depth of 1 to 10 metres occurred. The changed condition on the Bank is easily explained and agrees with previous records from the coast off Bergen (Gran 1927), and at the Lofoten Islands (Birgithe Ruud Föyn 1928). It is not possible to decide why the same condition did not exist outside Storeggen. We might imagine that the diatoms had remained somewhat longer out there, as the more abundant remains in the sample from 10 metres denote, whilst *Laboea conica* with its symbiotic algae may have helped to keep up the oxygen content in the surface layers. We must also realise the possibility that the Atlantic water columns have contained nannoplankton-forms, for which our preserving methods are not suitable.

Fifth Section, 12th May 1926.

Tables XXI—XXV.

The condition on the whole had not altered much. The thin surface-layer of water at the inner stations was again colder and of a higher salinity than it was a fortnight previously, and the salter waterlayers with the 34 ‰ curve as the limit, had once more risen towards the surface. Out at Storeggen the pure Atlantic water had given way a little to the colder surface-water with lower salinity.

The plankton was still very poor in diatoms. We could detect *Chaetoceras debile* in small numbers at the inner stations. At the Budground there even occurred in the surface layers a small maximum abundance of a little more than 5000 cells per litre of this species. Along with this form and of about the same number occurred *Ch. cinctum*. *Leptocylindrus danicus* still remained out at Storeggen, but in smaller quantities than previously.

The *Ceratium*-species on the whole were taken in the same numbers as before. All the species occurred on an average down to a depth of 25 metres as 44 cells per litre, of which *Ceratium longipes* with 27 cells per litre formed a large

part. At Storeggen (station 64) *C. longipes* had began to reproduce more rapidly. From the surface down to 10 metres the form was caught at the rate of 140 cells per litre. Out there the brown Infusories (with symbiotic flagellates) had reached their relative maximum abundance. *Laboea vestita* was present in the surface layers in a number of 1580 cells per litre.

The oxygen content in the surface-layers was about the same on the whole as that described in the last section. A small diatom maximum in the surface layers at the Budground (station 62) made its influence felt in an increase of oxygen of 0,27 cc.

Sixth Section, 1st—2nd June 1926.

Tables XXVI—XXX.

The temperature had risen over the whole area. In the surface layers in the Julsound it had gone up from 6,36 to 8,93° C., but on the whole the temperature was a little less out across the Bank. The temperature at Storeggen had gone down at a depth of 25 to 40 metres, owing to the displacement downwards of the 8° C. warm Atlantic waters.

The plankton showed a new flowering of diatoms at the station nearest land, in the Julsound. At the nearest station outside the Skerries (station 67) this flowering was just perceptible. The table shows that it was the same species, namely *Chaetoceras debile* and *Skeletonema costatum*, which were most prominant this time as at the last reproductive period in March, and *Chaetoceras debile* reached a still greater maximum number than it did in March—April, namely more than one million cells per litre. The distribution of the other species were about the same as before. Some forms which demand a high temperature to reproduce, such as *Chaetoceras cinctum*, *compressum*, *constrictum*, *curvisetum*, *Leptocylindrus danicus* and *minimus*, *Nitzschia delicatissima*, *Rhizosolenia alata* and *fragilissima*, and *Thalassiosira bioculata*, played a somewhat greater rôle now than they did in March. Of the arctic forms only *Eucampia groenlandica* occurred, even *Thalassiosira Nordenskiöldii* had disappeared. Strangely enough there had been a considerable increase in the oceanic species e. g. *Chaetoceras atlanticum* and *decipiens*.

The maximum abundance was not found in the surface layers, but at a depth of 25 metres. The maximum number for the diatoms must have passed by this time as they must have sunk down to this depth. This was also noticed in the distribution of the oxygen, as the oxygen content was much greater in 1 to 10 metres than at a depth of 25 metres, where the diatoms occurred.

It may seem remarkable that such a great number of diatoms had developed in such a short time, namely, nineteen days. But in accordance with the culture experiments made at Dröbak (Gaarder and Gran 1927) we know that the plankton diatoms under favourable conditions even in March with a temperature of 1 to 2° C., can reproduce daily at a rate of 80 %. To produce an increase from 100 to

1 million cells per litre, at such a rate of multiplication, they should require sixteen days. With still higher temperatures it would require less time. At 14° C. *Chaetoceras curvisetum* multiplied at a rate of 360 % in twenty-four hours. A period of nineteen days with a temperature of about 7° C. must therefore be more than sufficient for such an increase as we found in the Julsound. It is not necessary therefore to suppose that the diatoms had begun to reproduce somewhere else e. g. at the head of the Romsdalsfjord, and that they had been carried along with the current to the place where they were found.

The numbers of the diatoms at this time fell off considerably over the Bank. Already just outside the Skerries the numbers were hardly one tenth of what we found in the Julsound. It was only in the sample from a depth of 25 metres that we found any numbers of importance. Exactly the same species as in the Julsound were present and the same reciprocal proportion of numbers. The increase of plankton at the middle of the Bank (station 68) was still smaller and out at Storeggen (station 70) we did not find any increase at all. This second diatom-maximum number had developed thus exclusively close to the shore, and we can claim with full certainty that its origin was determined by the supply of nutritive salts from the land.

There was a distinct increase in the number of the *Ceratium*-species. The average number for all species together at a depth of 1 to 25 metres, was 116 cells per litre, and more than half of this was made up of *Ceratium longipes*. Clearly it was this form in particular, which had begun to reproduce and mostly at the two stations farthest out, where the number at a depth of 1 to 10 metres was a little above 200 cells per litre. We know from previous investigations of the development of the plankton along the coasts of Norway, that in June—July it is this species which defines the character of the plankton. This species comes first, and it is succeeded by *Ceratium tripos*, *fusus* and *furca*, which all demand a higher temperature to reproduce.

There was a decrease in the oxygen content of the water over the whole Bank but at the Julsound there was an increase, evidently on account of the metabolic process of the diatoms. The surface layers over the Bank were mostly just saturated or a little above, possibly on account of the rise in temperature of the surface waterlayers.

Seventh Section, 24th—25th June 1926.

Tables XXXI—XXXIII.

The rise in temperature of the surface waterlayers has continued but the salinity of the water had remained constant for the last three weeks.

Near land, the plankton-diatoms had continued to flower. In the Julsound *Chaetoceras debile*, which previously was the most prominent species, was now considerable less numerous, and instead there was an increase of such species as

Chaetoceras compressum and *Nitzschia delicatissima*. These demand a higher temperature. Great numbers of such typical southern forms as *Chaetoceras curvisetum* and *Schüttii*, and *Lauderia borealis*, and even species as *Guinardia flaccida* and *Rhizosolenia Shrubsolei* were recorded.

We found now the same plankton at the Budground at the middle of the Bank (station 80), but in small quantities. The low salinity showed that the plankton-carrying surface layers had moved from the shore. Out there *Chaetoceras debile* was still the most prominent species attaining 72.000 cells per litre. That it had passed its maximum figure was evident because greater numbers were found at a depth of 25 metres than in the surface layers.

There was still no suggestion of a new reproductive period of the plankton out at Storeggen.

A further increase in the numbers of *Ceratium*-species had occurred. Up to and including 25 metre we found all species reckoned together with a total maximum number of 156 cells per litre, of which 82 cells were *Ceratium longipes*.

The concentration of oxygen in the surface layers had decreased over the whole area.

The investigations for 1926 ceased here. It was desirable to get them supplemented the following year, because the first section (16th—18th of March 1926) had been rather late, and the flowering of plankton near land had already commenced. Also the determinations of oxygen owing to accident were not forthcoming for that cruise. It was considered advisable to undertake a cruise in 1927 therefore before the diatoms had begun to flower and also a second one during the main flowering season, in order that the increase of oxygen in the surface layers might be determined and a minimum value for the whole production during the development of the plankton be estimated.

Eight Section, 1st—2nd March 1927.

Tables XXXIV—XXXVIII.

The tables show that the flowering had just begun in February and as usual *Skeletonema costatum* was the first species to appear. Its maximum number at the Budground (station 102) reached over 100,000 cells per litre, but the oxygen content of the water in the surface layers was never more than just at saturation point.

It was very remarkable that *Asterionella japonica*, which in the next section appeared in enormous quantities, was found at this time as a single specimen at the station farthest out (station 104).

As in the previous year the *Ceratium*-species were at this time of year very few in number, but were evenly distributed. The total number of all species reckoned together in a depth from 1 to 25 metres was on an average 35 cells per litre of which

C. longipes numbered only two. *C. furca*, with an average of 12 cells per litre, was most frequent this year.

There was very little difference in the hydrographical conditions from March the previous year.

Ninth Section.

a) The Romsdalsfjord—Julsound 22nd March 1927.
b) The Julsound—Storeggen 28th—29th March 1927.

Tables XXXIX—XLVI.

The coastal waterlayers with a salinity between 33 and 35 $^0/_{00}$ had increased in volume, since the previous expedition was accomplished. The temperature was

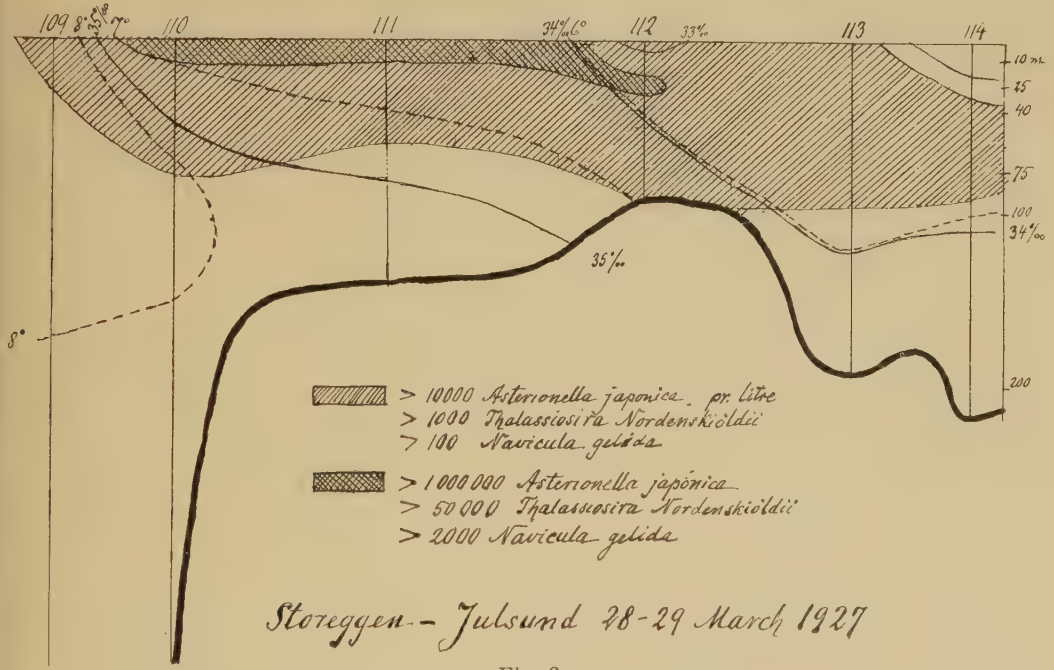

Fig. 3.

on the whole $^1/_2$° C. higher than the previous year at the same time. The development of the plankton was also farther advanced than in March 1926. We found a rich plankton all over the Bank right out to Storeggen. But at this time, as in 1926, there was a marked qualitative difference between the plankton out at Storeggen and that close to the shore, so that we got the definite impression that the development arose in two different areas.

Most striking was the fact that *Asterionella japonica*, which in 1926 only

played a minor rôle, was now the most numerous species from Storeggen and far in across the Bank with a maximum number of until one and a half million cells to the litre. On the other hand *Chaetoceras debile* played a comparatively minor part in 1927.

The difference between the plankton at Storeggen and the local one near land is best shown when we take the samples from the Romsdals fjord for comparison. Station 107 lies in the middle of the fjord outside Molde, where the different branches of the fjord meet and where the surface water layers through the Julsound come into contact with the various currents out on the Bank. Station 108 lies much farther up the fjord where it is surrounded by steep mountain-sides.

As the tables show the following species had their maximum number.

a) Out on the Bank:
Asterionella japonica (Station 111, 1,712,000 cells per litre).
Navicula gelida (Station 110, 5,200).

b) Their maximum number up the fjord:
Phaeocystis Pouchetii (Station 106, 11,900 colonies).
Lauderia borealis (Station 107, 7,030).
Chaetoceras furcellatum (Station 107, 14,400).
Chaetoceras curvisetum (Station 107, 19,200).

c) Two quite distinct maxima.
Chaetoceras debile.
The Bank (Station 110, 27,200).
The Romsdalsfjord (Station 107, 144,700).
Chaetoceras laciniosum.
The Bank (Station 111, 12,800).
The Romsdalsfjord (Station 107, 4,100).
Nitzschia seriata.
The Bank (Station 111, 2,400).
The Romsdalsfjord (Station 107, 1,500).
Skeletonema costatum.
The Bank (Station 111, 233,400).
The Romsdalsfjord (Station 107, 360,000).
Thalassiosira Nordenskiöldii.
The Bank (Station 110, 120,400).
The Romsdalsfjord (Station 107, 22,300).
Thalassiosira gravida.
The Bank (Station 111, 3,200).
The Romsdalsfjord (Station 107, 9,700).
Thalassiothrix nitzschioides.
The Bank (Station 110, 6,800).
The Romsdalsfjord (Station 107, 31,700).

Table 4.

Asterionella japonica. Storeggen—Romsdalsfjord 22—29 March 1927.

m.	St. 109	St. 110	St. 111	St. 112	St. 113	St. 114	St. 107	St. 108
1.....	330600	1507800	1535200	93800	424800	280	500	600
10.....	271300	1218400	1712000	145400	758600	5000	2700	4900
25.....	109920	358920	177400	1198900	874000	3100	1400	1200
40.....	1820	76960	150480	285300	424800	65000	680	840
75.....	..	19360	1720	213000	265800	55060	90	..

Chaetoceras debile. Storeggen—Romsdalsfjord 22—29 March 1927.

m.	St. 109	St. 110	St. 111	St. 112	St. 113	St. 114	St. 107	St. 108
1.....	500	27200	12200	..	800	160	18440	840
10.....	1300	12600	16400	..	360	3800	81900	2280
25.....	200	2120	..	2800	2360	6140	144700	240
40.....	..	..	1040	..	6800	21680	3540	..
75.....	200	180	..	..	180	..	..	..

Skeletonema costatum. Storeggen—Romsdalsfjord 22—29 March 1927.

m.	St. 109	St. 110	St. 111	St. 112	St. 113	St. 114	St. 107	St. 108
1.....	58700	47200	233400	..	1000	11040	147920	380200
10.....	68300	77400	201600	1600	5360	36600	306000	32160
25.....	25880	29240	216800	18100	11480	30640	180800	27560
40.....	380	9400	180640	7000	8840	22280	198200	5140
75.....	120	6020	4240	7160	500	12440	1720	1840

Thalassiosira Nordenskiöldii. Storeggen—Romsdalsfjord 22—29 March1927.

m.	St. 109	St. 110	St. 111	St. 112	St. 113	St. 114	St. 107	St. 108
1.....	18700	120400	16400	9000	6120	..	6160	120
10.....	23200	89200	75200	46200	5080	640	22300	800
25.....	13960	14440	8800	59500	3920	580	2200	..
40.....	..	6080	9960	7700	3400	440	980	..
75.....	..	2040	520	4980	6400	1040	..	..

The remaining species are not noted here, as they were only found in so small quantities, that the variations between the observed figures may lie within the limits of the counting error. Taking the plankton as a whole, we find two marked

production-maxima. One lies on the Bank out towards Storeggen, at Stations 111 and 110, the other one at the outer part of the Romsdalsfjord, Station 107, and out towards the Julsound, Stations 106 and 114. Both maxima finally float out and merge with each other at the inside of the Bank, Stations 112 and 113.

It is quite certain that we can claim with regards to the production of the inner maximum that the individual species as well as the nutritive conditions which had caused their mass-development, were of local origin. The other maximum out on the Bank must have developed from cells which the current had brought from the south, either from the north of the North Sea or from the Faroe-Shetland Channel. We can conclude this, because the plankton first and foremost was characterised by *Asterionella japonica*, which is generally a rare visitor in these waters, and also, that in 1927 as well as in 1926, we found here the typical Atlantic form *Oxytoxum diploconus* (at 40 metres, Station 110). We might ask the question whether the nutritive salts, which made the plankton development possible out there, had come to the surface layers by vertical circulation along Storeggen, or, if these salts had come along in the currents from the Scottish coastal waters. We found exactly the same species in the pure Atlantic water outside Storeggen (Station 109), but in much smaller quantities. At Storeggen (Station 110) we got the same species, but by far the greatest number in the surface layers down to about a depth of ten metres in water layers with a salinity of about 34.5 ‰ and a temperature of less than 7° C. This might perhaps indicate that the nutritive salts also came from the south in the currents. But on the other side, the hydrographical observations show, that temperature, salinity and density, of the water was so evenly distributed at the beginning of March, that a vertical circulation down to great depths may have taken place.

Since the beginning of March the determinations of the oxygen content showed a considerable increase in the surface layers and at the inner stations also deeper down.

Table 5. The increase in the content of oxygen from 1st—2nd to 28th—29th March 1927.

Stations.....	114 (105)	113 (101)	112 (102)	111 (103)	110 (104)
metres					
1.....	+0.40	+0.76	+0.65	+0.95	+0.95
10.....	+0.28	+0.42	+0.82	+0.65	+0.92
25.....	+0.50	+0.44	+0.45	+0.09	—0.03
40.....	+0.55	+0.43	+0.31	+0.21	—0.01
75.....	+0.11	+0.54	+0.09	+0.16	—0.23

The increase was smallest in the Julsound and greatest on Storeggen and at the outer side of the Bank. But while we at Storeggen found an increase in the tension of oxygen in the surface layers only down to a depth of ten metres, we

found an increase in the content of oxygen in the water near land down to a depth of forty metres, and at a single station (Station 113) just outside the Skerries we found an increase of oxygen even down to a depth of seventyfive metres. The same difference was found when we compared the percentage of the saturation of oxygen at the different stations (Table 6) and the values of P_H at the same stations (Table 7).

Table 6. The percentages of the saturation of oxygen 28th—29th March 1927.

Stations	114	113	112	111	110
metres					
1	106.9	110.5	109.1	111.5	112.0
10	105.9	105.6	108.1	109.8	110.5
25	104.2	103.0	102.8	97.5	99.2
40	104.0	103.1	99.1	100.9	96.7
75	97.0	103.2	97.8	94.2	96.9

Table 7. The values of P_H 28th—29th March 1927.

Stations	114	113	112	111	110
metres					
1	8.21	8.25	8.26	8.25	8.28
10	8.16	8.23	8.19	8.24	8.25
25	8.18	8.19	8.13	8.01	8.12
40	8.19	8.15	8.10	8.06	8.05
75	8.13	8.18	8.13	8.09	8.01

The determinations of the plankton and the values of the oxygen and P_H on the whole agree with each other apart from the unaccountably high value of oxygen at Station 111 at a depth of forty metres. The more remarkable thing was, however, that we found an increase in the oxygen and higher values for P_H down at a depth of seventyfive metres at the three stations nearest land, and particularly at Station 113, just outside the Skerries. One explanation of the conditions might be that the diatoms during their development gradually sank down to that depth and continued their photosynthesis there. The cultural experiments at Dröbak (Gaarder and Gran 1927)[1]) showed however, that the light at such great depths was not strong enough to carry on photosynthesis sufficiently strong to keep the balance with respiration. The balance for the diatoms at Dröbak lay at a depth of about ten metres. Even if we take into consideration the fact that the flasks of the culture experiments might have absorbed some light, and that the upper plankton-carrying waterlayers at Dröbak might be less transparent than those in the present case, the difference is, however, too great to be explained in this

[1]) Marshall and Orr in a paper just published (1928) state that the equlibrium between photosynthesis and respiration of plankton diatoms *(Coscinosira polychorda)* in Loch Striven lie between 10 m. and 30 m. according to the season.

manner. The cultural experiments (March 1916) were conducted at the same time of year and more than 3° further south, and no great difference between the amount of plankton in the two cases was noted.

Gaarder has come to the conclusion by calculating the average distribution of oxygen along the westcoast of Norway, that the algae by their assimilation, influence the tension of oxygen down to a depth of forty metres. We must, however, take into account the possibility that this statement gives not an accurate measure with regard to how deep such quantities of light may penetrate the water, that a photosynthesis sufficiently strong to balance the respiration may take place. On the westcoast of Norway as outside the coast of Romsdalen the water columns are constantly moving and the rotation of the earth must wedge together the specifically lighter surface waterlayers. Dr. Martens, who worked up the hydrographical material from these investigations, has been kind enough to inform me that such wedging of the surface layers of the coastal water towards land will occur regularly at places where there is an increase in the rate of motion. Just at the narrow Bank outside Romsdalen, there is reason to believe that the current is stronger here than it is farther south and farther north. This wedging together of the surface water was strongest close to the shore, and I consider it absolutely certain that the surplus oxygen at a depth of forty metres and even at a depth of seventyfive metres had not originated in those depths, but was caused by the diatomcarrying-waterlayers being pressed down into deeper water, the diatoms having raised the concentration of oxygen and the value of P_H of these waterlayers at an earlier date, while the water layers were nearer at the surface.

Printz (1926, p. 33) has shown that the limit to the depth for the fixed algae-vegetation of species such as *Turnerella septentrionalis*, *Phycodrys sinuosa*, and *Ostreobium Queketti* outside the Trondhjemsfjord, under similar condition as at the coast of Romsdalen, lies at 29—30 metres. Further up the fjord where the surface layers gradually grow more and more opaque owing to mud and detritus, the limit to the depth lies nearer the surface and at the head of the fjord, at Rauskjær, *Phycodrys sinuosa* does not grow further down than a depth of 10—11 metres. The specimens near their depth-limit developed slowly and did not attain the normal size. The fixed vegetation is exposed to a change able luminosity, the conditions varying according to the density of the plankton. At the time of year when the plankton is scarce in the water the light must penetrate its way deeper down than during the period when the diatoms attain their maximum production. During that time therefore the balance between the katabolism and the anabolism cannot lie deeper down than thirty metres under any circumstances, probably still nearer to the surface.

In the Romsdalsfjord the limit between the surface layers rich in plankton and the very poor deeper layers at the head of the fjord (Station 108) lies at a depth of something over twentyfive metres, and about half up the fjord, (Station 107)

at a depth of forty metres or a little more. This agrees with the results of Mr. Printz, namely that the limits lie higher at the head of the fjord than further down. But we must also allow for the possibility that the surface layers may be compressed in the fjord. Such a condition will occur as a rule after the wind has been blowing on the shore (cf. Gran and Gaarder 1918). In this case it would be a westerly wind. The rich plankton carrying surface layers in the Romsdalsfjord were sharply separated from the deeper waterlayers not only by their plankton, but also by the temperature, salinity and the specific weight of the water, in March 1927. Also every condition existed so that the surface layers could be moved very easily about by the wind. The observations taken at Ona lighthouse, the nearest meteorological observation-station, also showed that a strong wind had been blowing on the shore almost incessantly for the five days previously to March 22nd. According to a chart for the force of wind from 0 to 12, the wind at Ona was:

1927	March	17th	WSW.	Force 5
—	—	18th	WSW.	— 3
—	—	19th	SSW.	— 4
—	—	20th	SW.	— 7
—	—	21st	W.	— 7
—	—	22nd	E.	— 1

It is therefore very probable that the situation in the open Romsdalsfjord across from Molde on the 22nd of March was due to a compression of the surface layers.

If we try to obtain the amount of the total production of organic material during the spring maximum abundance of the diatoms outside the coast of Romsdalen, we can start from the fact that there is an increase in the oxygen of at least 0.5 cc. per litre at the surface layers down to a depth of ten metres, from the shore out to Storeggen, that is to say 48′ from the coast, corresponding to 7 grams sugar per square metres. The greatest part of this increase will have occurred during the last ten to twelve days of March. This calculation is sure to give too low a value, because if we take into account the increase of oxygen in the deeper waterlayers we get considerably higher values (cf. p. 58). In 1927 I found when doing a similar calculation off Bergen, twice as high a value, and at the banks at the Lofoten Islands Birgithe Ruud Föyn calculated a still higher production per square metre. All these calculations can only give the minimum values and so many factors may overlap and thus effect the balance between the anabolism and katabolism, as well as the exchange of oxygen between the sea and the atmosphere, that the difference between the calculated values at the various places may be of the same size order as the limits of error in the calculation. So much can be said, however, that at all the three places, each of which may be supposed to represent an essential part of the Norwegian coastal waters, have an amazingly high production over a great area during a short period.

We know up to the present of still higher values for the production of organic material by the plankton only from such regions as the Bay of Kiel from the work of PÜTTER (1924) and from Loch Striven in the Clyde Sea Area from the valuable investigations of MARSHALL and ORR (1927).

Notes on the species.

1) *Halosphaera viridis*, SCHMITZ. This species was found individually at the beginning of the season. It has been recorded previously from this region particularly during the winter. It has a tendency to float quite near the surface, so perhaps the centrifuged samples do not give the right impression of its presence here.
2) *Eutreptia Lanowii*, STEUER. This form occurred through the whole season and usually near land. The maximum numbers were 300 cells per litre, and were taken in the Romsdalsfjord on the 22nd of March 1927 at a depth of 10 metres.
3) *Phaeocystis Pouchetii*, LAGERH. This form has been taken during the month of March in the Romsdalsfjord and the Julsound, and sometimes in great abundance. The quantitative determination was rather difficult, because the colonies got broken in the samples.
4) *Pterosperma dictyon* (JÖRG.). The form has only been taken individually.
5) *Pterosperma Vanhöffeni* (JÖRG.). This species was also only taken individually.

Diatomaceae.

6) *Achnanthes taeniata*, GRUN. This distinctly arctic-neritic species was taken in the Julsound and in the Romsdalsfjord in 1926 and 1927, but each time only single chains were found.
7) *Actinocyclus Ehrenbergii*, RALFS. This form occurred throughout the whole season, both close to the shore and out at Storeggen. It was present mostly in the samples from a depth of forty to seventyfive metres, but only individual specimens in the 50 cc.-samples were found.
8) *Actinoptychus undulatus* (BAILEY). Only individual specimens were obtained of this species. It was recorded twice in a depth of forty and seventyfive metres, and in both cases before the diatom-flowering had begun.
9) *Asterionella japonica*, CLEVE. The appearance of this form is very peculiar. It was never recorded from this region in 1898—1900. Its distribution centre in the northern Atlantic had previously been recorded as the waters along the south-coast of Iceland. According to the International Investigations of the Sea 1902—1907 worked out by OSTENFELD (1913) it has been recorded from the English Channel, on the north-east coast of Scotland, scattered in the North Sea and in the Skagerrack. In the English Channel it was found in great

abundance in February with a maximum number in April. At the other areas it was recorded with a maximum number in May, and on the south and west coasts of Iceland from May to June. Its optimum-temperature according to previous observations, lies about 8° C.

In 1926 it was obtained from March-April over the whole Bank from Storeggen and to the shore. It appeared first (March 27th) out at Storeggen, in April at the middle of the Bank with a maximum number of 11,000 cells per litre. Birgithe Ruud Föyn (1928) recorded it the same year from the edge of the shelf outside the Lofoten Islands, but there too it appeared in comparatively small numbers.

In 1927 on the 28th of February it occurred in great abundance at Dröbak in the Oslofjord with a maximum number of 188,000 cells per litre along with the most characteristic forms of the Sira-plankton, namely *Thalassiosira Nordenskiöldii* and *Skeletonema costatum*. It remained here until the 28th of April at least, when it reached a maximum number of 620,000 cells per litre at a depth of ten metres. At my request, Professor Aug. Brinkmann was kind enough to arrange for water samples to be collected and preserved in the Hjeltefjord by the Biological Station at Herdla near Bergen. Here the form occurred in abundance on March 10th and 18th. The maximum numbers were about 200,000 cells per litre. Later on it disappeared. According to verbal information from Professor Ostenfeld it was recorded in 1927 in abundance in Danish waters as close to land as the harbour of Copenhagen.

Individual specimens were found at the coast of Romsdalen as early as March 1st out on Storeggen. At the end of March it had multiplied greatly. Farthest out on the Bank, it was the most predominant species with a maximum number at Station 111 of more than one and a half millions cells per litre in the surface layers (1 to 10 metres). Here it conquered the area which in 1926 was held by *Chaetoceras debile*. It was also recorded as far in as the Romsdalsfjord, but in small quantities (up to 5000 cells per litre).

It would have been interesting to know if the form had reached as far north as the Lofoten Islands that year. The cruise, which in 1927 was conducted across the Bank out to the edge of the shelf, Vesterålseggen, was delayed unfortunately on account of a gale, until 22nd—26th of April, and the diatom-plankton out there had already disappeared by this date. Mr. Gunnar Rollefsen was kind enough to send me a series of townet-samples from the Vestfjord taken from March-April 1927. But these only contained the characteristic arctic-neritic plankton, which Mrs. Föyn has described already from the previous years, and which were also known from previous investigations (Hjort and Gran 1899, Gran 1900, Jörgensen 1905).

Asterionella japonica in 1927 had made apparently a great advance towards the North. Its maximum number was found in the last part of March

in waterlayers with a temperature 6.5° C. to 6.6° C. and a salinity of 34.4 to 34.5 ‰. Out on Storeggen, the temperature was 8° C. and the salinity 35 ‰, but at the middle of the Bank, where over one million cells per litre were still found, the temperature was below 5.4° C. and the salinity below 33.6 ‰.

It would be very interesting to find out whether this species, like *Biddulphia sinensis*, will retain the new area of expansion which it has conquered (Ostenfeld 1909), or if it will disappear again. In 1927, conditions which were particularly favourable for its multiplication must have been prevalent. It has undoubtedly journeyed to our area either with the current from the coastal waters round about Shetland, where the form in previous years has been observed as early as February although in small quantities, or else it has travelled along the coast of Norway from the Skagerrack, where it had journeyed very probably from the southern part of the North Sea.

10) *Asteromphalus heptactis*, (Bréb.). This form appeared individually and usually in Atlantic waters.
11) *Bacterosira fragilis*, Gran. Single specimens of this form were caught in the Julsound.
12) *Biddulphia aurita* (Lyngb.). In the present material the form appeared rather rarely. It was only found in March from the Julsound out to Storeggen.
13) *Cerataulina Bergonii*, Peragallo. This species was caught in March and April and it appeared scattered from the Romsdalsfjord to Storeggen, but always quite subordinately, the maximum number (600 cells per litre) being found at the head of the Romsdalsfjord.
14) *Chaetoceras atlanticum*, Cleve. This oceanic species was obtained in quite subordinate numbers. Strange to say we found it relatively in greatest numbers in the Julsound in June 1926 with a maximum number of 1000 cells per litre.
15) *Ch. boreale*, Bailey. This form too, oceanic as the previous one, was found in quite subordinate numbers, scattered through our material from March to June, in the whole area from the Romsdalsfjord out to Storeggen. The maximum number, about 1000 cells per litre, was found at the outer part of the Bank in March-April.
16) *Ch. boreale* f. *varians*, Gran (*Ch. criophilum*, Cleve, Gran; *Ch. concavicorne*, Mangin). In April 1926 this species was caught occasionally in the Julsound.
17) *Ch. breve*, Schütt. This form was observed in small quantities in April 1926 at the outer part of the Romsdalsbank.
18) *Ch. cinctum*, Gran. This form was also scarce from May-June 1926. The maximum number, 13,000 cells per litre, was taken on the 1st of June in the Julsound. At Storeggen resting spores were found on the 2nd of June.
19) *Ch. compressum*, Lauder (*Ch. contortum*, Schütt). This species occurred throughout the whole season. It was more scarce in March. The maximum number was found close to the shore during the secondary diatom-maximum

in June 1926, when more than 60,000 cells per litre were taken in the surface layers in the Julsound on the 24th of June.

20) *Ch. constrictum*, Gran. This boreal-neritic species was found occurring as a rule quite subordinately in March. It was more common at the outer side of the Romsdalsbank than nearer land. In April it was caught in greater numbers with a maximum abundance of about 20,000 cells per litre, at a depth of from one to ten metres, at the Budground (Station 48) on the 9th of April 1926.

21) *Ch. convolutum*, Castracane. This species was of quite subordinate importance. It was found from March to June with a maximum number of 800 cells per litre at Storeggen, on the 27th of March 1926.

22) *Ch. curvisetum*, Cleve. This species requires too high an optimum-temperature to be able to play a dominant part in our area as early in the year as the samples were collected, but it is obviously stationary. We found it in the Romsdalsfjord on the 22nd of March 1927 with a maximum number of almost 20,000 cells per litre. It was also caught, if not in such great numbers, in the more oceanic waters which move along the outer side of the Romsdalsbank; e. g. on Storeggen. 1600—1900 cells per litre were obtained on the 27th of March 1926.

23) *Ch. debile*, Cleve. This was the most prominent species in this region both from March-April as well as during the secondary maximum number in June 1926. It is stationary as the investigations from 1898—1900 show, and as in 1926, it may form the bulk of those diatoms which flower out at Storeggen. At this place a maximum number was reached on the 27th of March 1926, namely more than 300,000 cells per litre. In 1927 the numbers were hardly one-tenth of this number because it was greatly outnumbered by *Asterionella japonica*. In the Julsound, close to the shore, it reached a maximum number of almost one million cells per litre on the 10th of April 1926. During the secondary maximum abundance on the 1st of June 1926 it even more than exceeded one million cells per litre in number. It seems to have a higher optimum-temperature than the Sira-plankton's characteristic species. Ostenfeld (1913[b]) calculated the optimum-temperature for *Thalassiosira Nordenskiöldii* as 5.3° C. (0.8—10.6° C.) and for *Chaetoceras debile* as 7.7° C. (5.25—12.35° C.)[1]). These limits with regard to the last species must be too narrow however. The great maximum abundance in March 1926 had developed at a temperature below 4.5° C.

24) *Ch. decipiens*, Cleve. Though this species is a typical oceanic form, it was found in greater quantities close to the shore than at Storeggen and at the

[1]) In Ostenfeld's paper p. 487 the minimum and the maximum temperatures must have been changed by a printers error.

Bank. The maximum number 6400 cells per litre was reached in the Julsound on the 1st of June 1926.

25) *Ch. densum*, Cleve. This form was found singly at Storeggen on the 29th of April 1926.

26) *Ch. diadema*, (Ehr.). This species had its maximum number, 36,800 cells per litre, on the 27th of March 1926. It is recorded in our material as more numerous out on the Bank than close to the shore, but here it is surely stationery.

27) *Ch. didymum*, (Ehr.) was caught on the 28th of March 1927 both on Storeggen and on the Bank, but only single specimens were found.

28) *Ch. furcellatum*, Bailey. This is an arctic-neritic species, of which the maximum number, 14,400 cells per litre, was found at the Romsdalsfjord on the 22nd of March 1927, and at that date resting spores had already been formed. The species is stationary.

29) *Ch. laciniosum*, Schütt. This form was less regular in its appearance than the other *Chaetoceras*-species. It had a distinct maximum abundance on the 27th of March 1926 at Storeggen, namely 200,000 cells per litre at a depth from 1 to 10 metres. A considerable decrease in the numbers occurred a fortnight later out at Storeggen. We found its maximum number, 10,000 cells per litre, now inside the Julsound. The species played a far less prominent part in the plankton of 1927. Its maximum number then (12,800 cells per litre), was recorded on the 29th of March at Station 111 (out on the Bank).

30) *Ch. pseudocrinitum*, Ostenfeld. Single specimens were taken in the Julsound on the 24th of June 1926.

31) *Ch. Schüttii*, Cleve. This species played at this time of year a very secondary rôle. Its maximum number, 3600 cells per litre, was recorded from the Julsound on the 24th of June 1926. The form is undoubtedly stationary.

32) *Ch. scolopendra*, Cleve. Both in 1926 and in 1927 this species had its maximum number out at Storeggen, namely 24,000 cells per litre on the 27th of March 1926, and 13,000 cells per litre on the 28th of March 1927.

33) *Ch. simile*, Cleve. This quite subordinate species occurred scattered over the whole area during March of both years.

34) *Ch. sociale*, Lauder. This form had its maximum number early, on March 18th 1926 in the Julsound. As long as the chains were united in big colonies they were very difficult to count. Later on when the single chains with their resting spores were floating along it was easier to count. Most of our samples only contained very small chains. It is certain that the species plays a greater part in the plankton, specially close to the shore, than the impression given by the tables.

35) *Chaetoceras teres*, Cleve. This form appeared both stationary and among the floating plankton out on the banks. The maximum number, 10,000 cells per

litre, was found at Storeggen on the 27th of February 1926 at a depth from 1 to 10 metres. It is quite subordinate.

36) *Corethron criophilum*, Castr. On the 9th of April 1926 this oceanic species was caught singly out at Storeggen.

37) *Coscinodiscus centralis*, Ehr. Single specimens of this form were obtained in the Julsound and at the Bank.

38) *C. concinnus*, W. Smith. This species was caught particularly in the Romsdalsfjord, and in the Julsound. The maximum number, namely 120 cells per litre was obtained on the 1st of June 1926.

39) *C. excentricus*, Ehr. was caught singly at Storeggen from March to June 1926.

40) *C. radiatus*, Ehr. This form was scattered over the whole area during March and April, but very rarely more than one specimen was found in a 50 cc. sample. It is mostly taken a little below the surface waterlayers.

41) *C. stellaris*, Roper. In March 1927 this species was caught singly both in the Julsound and in the Romsdalsfjord.

42) *C. subbulliens*, Jörg. Single specimens of this species were obtained farthest out on the Romsdals Bank and at Storeggen 1926.

43) *Coscinosira polychorda*, Gran. This species was rather more common than the tables show. When the connection between the chains break the single cells may very easily be mistaken for *Thalassiosira gravida*. It was obtained both close to the shore as well as in the current out at Storeggen. It reached its maximum number, 2700 cells per litre, in the Romsdalsfjord on the 22nd of March 1927, and we also found the form at the secondary maximum at the Julsound on the 1st of June 1926, namely 8 to 900 cells per litre. It reached its maximum number, 2000 cells per litre, out on the Bank, Station 111, on the 29th of March 1927.

44) *Dactyliosolen tenuis*, Cleve. Individual specimens were taken at the further end of the Bank on the 1st of March 1927.

45) *Eucampia groenlandica*, Cleve. This form was rarely taken on the Romsdalsbank. It is a subordinate part of the local arctic-neritic plankton in the Romsdalsfjord and the Julsound.

46) *E. Zoodiacus*, Ehr. This species was caught individually on the innermost part of the Bank.

47) *Fragilaria oceanica*, Cleve. This form is also a subordinate part of the local arctic-neritic plankton in the Julsound and in the Romsdalsfjord in March. The maximum number in the Romsdalsfjord, 10,000 cells per litre was obtained on the 22nd of March 1927.

48) *Guinardia flaccida* (Castr.) is a southern neritic species, and in our material it was recorded individually from the Bank and the Julsound in April-June 1926.

49) *Gyrosigma fasciola*, Cleve. This littoral form was occasionally found among the plankton.

50) *Lauderia borealis*, Gran. During spring this species was rather subordinate with a maximum number in the Romsdalsfjord up to 7000 cells per litre, on the 22nd of March 1927. When a local diatom-plankton develops owing to a higher temperature during the autumn this species will very probably play a relatively greater part. It was stationary in the Romsdalsfjord and at the Skerries, but only occasionally taken out on the Romsdals Bank.

51) *Lauderia glacialis*, (Grun.) appeared locally and out on the Bank, mostly from March-April. A maximum number up to 7000 cells per litre was found in the Romsdalsfjord in March 1927. A second one, 6200 cells per litre, was taken farthest out on the Bank (Station 111), otherwise it was only caught in smaller quantities.

52) *Leptocylindrus danicus*, Cleve. This species played a very secondary part in the plankton from March-April close to the shore, and not until June did it reach a number worth mentioning (4000 cells per litre). Out on the Bank it was caught in somewhat greater numbers especially in 1926, with a maximum of 11,000 cells per litre at Station 48 (the Budground) on the 9th of April 1926. It probably demands a high temperature so that it cannot play a prominent part in the plankton as early in the year at such a high latitude.

53) *L. minimus*, Gran. In our material this form was chiefly recorded from the fjord and close to the shore. The maximum number was obtained on the 1st of June 1926, 22,200 cells per litre, in the Julsound. This number is of no consequence whatsoever for such small forms in comparison with the other forms and with the frequency which this species may obtain in other localities e. g. in the Hardangerfjord (Gran 1927).

54) *Navicula directa*, W. Smith. Considering this is a littoral form, this beautiful characteristic species was caught rather frequently, mostly in the Julsound and farthest in on the Bank.

55) *Navicula gelida* Grun. A little *Navicula* living regularly together with plankton diatoms, often on the *Chaetoceras* chains I have in my earlier papers only recorded as *Navicula* sp. The cells are 35—40 μ long and 7—9 μ broad. Valves with very fine striae close in to the narrow middle rib. No axial or central area. I regard it as a variety of *N. gelida*.

Though we must recognise this species as a littoral form, it must undoubtedly, however, in accordance with the regular manner in which it appears, multiply among the plankton-diatoms in a floating condition. It is recorded in our material in greater numbers out on the Bank than close to the shore. We found it on the 29th of March 1927 out on Storeggen in number exceeding 5000 cells per litre, and here it had its maximum abundance. At the same time we found only a few hundreds close to the shore. The same was also the case on the 9th of April 1926, when it reached a maximum number of 3500 cells per litre at the middle of the Bank, and this year too its maximum num-

ber was obtained farthest out on Storeggen (March 27th 1926, 3700 cells per litre).

56) *Nitzschia Closterium*, W. Smith. This species we found scattered through the whole material, but rarely in any great numbers. The maximum number (2200 cells per litre) was obtained in the Julsound on the 1st of June 1926.

57) *N. delicatissima*, Cleve. From March-April this form was quite subordinate. We found, however, a maximum number of 25,000 cells per litre on the 22nd of March 1927 at the head of the Romsdalsfjord. During the secondary plankton season, on the 1st of June 1926, this species played a relatively more prominent part. We found on the 1st of June 1926 in the Julsound a maximum number of 28,000 cells per litre and on the 24th of June 1926 a maximum number of 58,000 cells per litre.

58) *Nitzschia seriata*, Cleve, was found as a rule in the plankton samples from March-April though not very numerous. It was obtained in greater number at Storeggen and farthest out on the Bank than near land. In 1926 the maximum number at Storeggen, on the 27th of March, was 5600 cells per litre. On the 28th of March 1927 the maximum number farthest out on the Bank (Station 111) was 2400 cells per litre. In the Julsound the number taken in June 1926 was 2—3000 cells per litre. According to this it flowers closer to the shore later on than out at Storeggen, perhaps owing to temperature.

59) *Paralia sulcata*, Ehr. This form undoubtedly had floated along with the current from the south. Individual specimens were caught mostly out on the Bank and particularly before the main spring-flowering had begun.

60) *Pleurosigma Normanni*, Ralfs. This is a littoral form, sometimes recorded in the plankton. In 50 cc. samples either one or a few individuals only were observed.

61) *Rhizosolenia alata*, Brightw. This species was rather scarce in the first half of the year and mostly found close to the shore. In the Julsound in the latter part of March 1927 and on the 24th of June 1926 it reached up to 300 cells per litre. A maximum number in the Romsdalsfjord also occurred. According to previous qualitative investigations it is found quite commonly at the outer part of the Bank in the late summer.

62) *R. calcar avis*, Schulze. Individual specimens of this species were caught in the Julsound on the 29th of March 1927.

63) *R. Faeroensis*, Ostenfeld. This species is probably only a bigger form of the following species, but as it is very easily distinguished it is more practical for the present to deal with them separately. The form reached its maximum number, 3200 cells per litre, out at Storeggen on the 29th of March 1927. It is stationary without doubt on the coast of Romsdalen. On the 24th of June 1926 it reached the number of 600 cells per litre in the Julsound.

64) *R. fragilissima*, Bergon. Similar to the previous species this form was quite

subordinate, but was caught during the spring in somewhat greater numbers. It had its maximum number, 2500 cells per litre, in the Romsdalsfjord in March 1927, and another one out at Storeggen with a maximum number of 2800 cells per litre. During the second maximum in the Julsound on the 1st of June 1926 the number recorded was 8200 cells per litre.

65) *R. semispina*, Hensen (really *R. hebetata* (Bail.) f. *semispina*). This species had its maximum number, 2200 cells per litre, at Storeggen in March 1926. On the 9th of April 1926 the maximum number, 2800 cells per litre, was found at the Budground. It had apparently moved nearer land. On the 28th of March 1927 it had again its maximum at Storeggen with 1400 cells per litre. In our area the form seems to come in over the Bank chiefly from further out, probably from the south.

66) *R. setigera*, Brightw. Both times this species was recorded, it was taken on the inner side of the Bank and only singly.

67) *R. Shrubsolei*, Cleve. This form is very rarely obtained at this time of year. In March 1927 it has only been recorded from the head of the Romsdalsfjord. It was taken in somewhat greater number (120 cells per litre) in the Julsound in June 1926. Later on in the summer it has been caught on the Bank along with *R. alata*.

68) *R. Stolterfothii*, Perag. This species was obtained at Storeggen on the 29th of March 1927. It had probably been carried along with the current from the vicinity of Shetland. In June 1926 it was recorded from the Budground.

69) *Skeletonema costatum*, (Grev.). In our area, as well as at many other places (near Bergen, on the west-coast of Scotland, and at the Lofoten Islands) this species is the first to begin its development after the winter rest. By March 18th 1926 it had already reached a maximum number of 600,000 cells per litre in the Julsound. There was a regular and slow decrease until the 10th of April, when we found its maximum abundance was 288,000 cells per litre, at a depth of 40 metres. At the station just outside the Skerries, Buddypet, the development was quite the reverse. On the 16th of March 1926 it was only found in very small quantities. It multiplied until more than two millions was reached on the 9th of April. The maximum number was obtained at a depth of 40 metres, which was a sign that the main flowering had passed.

At the next station outside the Budground we met with similar conditions, but the maximum number namely 418,000 cells per litre on the 9th of April, was found still in the surface layers. Out at Storeggen in 1926 only very small quantities were found. The masses of *Skeletonema* in 1926 had apparently begun their flowering near land, and the maximum number had gradually moved out towards the Budground until the diatoms at the end of April disappeared from the whole region.

In March 1927 *Skeletonema* was recorded from the whole area. On the first

of the month it was scarce with a small maximum abundance (109,000 cells per litre) at the Budground. At the end of the month it had two maxima, one farthest out on the Bank with a maximum number of more than 200,000 cells per litre, and another one at the head of the Romsdalsfjord of 380,000 cells per litre. It is possible that the development that year had originated both from the stationary individuals as well as from cells carried from the south past Storeggen.

70) *Thalassiosira bioculata*, (Grun.). This form was rather scarce in March, but it was found in June 1926 in the Julsound up to 3—400 cells per litre.

71) *T. decipiens* (Grun.). This form appeared regularly and began to flower like *Skeletonema* early in the year, but was never caught in any great numbers. Its maximum number (12—1600 cells per litre) in 1926 was found on the 26th of March in the Julsound. In 1927 its maximum number (6—8000 cells per litre) was found farthest out on the Bank on the 29th of March.

72) *T. gravida*, Cleve. This species in our northern waters is very numerous and evenly distributed. In our region it is both stationary and is brought along with the current from outside. In 1926 its maximum number occurred first out at Storeggen, with 30,000 cells per litre on the 27th of March of that year. On the 9th of April 1926 its maximum abundance, 19,000 cells per litre, still lay on the outer part of the Bank. That year the greatest number thus seems to have come from outside. In June 1926 we found the species as a subordinate part of the secondary local maximum near land.

On the 1st of March 1927 it was found scattered over the whole Bank, but was not very numerous. At this date its maximum number was 1000 cells per litre, at the middle of the Bank (Station 102). At the end of the month we obtained it over the whole area, but with two separate maxima, the one in the Romsdalsfjord with a maximum number about 10,000 cells per litre, and the other at the outer part of the Bank with a maximum number of 3000 cells per litre. In 1927 the stationary stock thus seems to have formed the principal basis for its development.

73) *T. hyalina* (Grun.). This is an arctic-neritic species which forms a subordinate part of the stationary plankton. The maximum number, 1300 cells per litre, was obtained in the Romsdalsfjord on the 22nd of March 1927.

74) *T. sp.* A very small species occurred in March 1926, with maximum (18000 cells per litre) at Storeggen.

75) *T. Nordenskiöldii*, Cleve. In 1926 the flowering of this species first began in the Julsound with a maximum number of 1700 cells per litre in a depth of one metre on the 18th of March. A week later, on the 26th of March, there was an increase in the maximum number up to 3600 cells per litre. A much greater increase occurred at the same time out at Storeggen. On the 27th of March 1926 there were more than 10,000 cells per litre at Station 46. We found it

evenly distributed over the whole of the Bank on the 9th of April with a maximum number of 17,000 cells per litre at the Budground (Station 48).

In 1927 at the end of March we observed two separate maxima, one in the Romsdalsfjord with a maximum number of 22,000 cells per litre, and another and much bigger one out at Storeggen with a maximum number of 120,000 cells per litre. The species is therefore in our area both stationary and allogenetic.

76) *T. subtilis*, Ostenf. This is an oceanic form which was occasionally caught at Storeggen from April to June 1926.

77) *Thalassiothrix longissima*, Cleve and Grunow. Individual specimens of this oceanic species were obtained, mostly out on the Bank.

78) *T. nitzschioides*, Grun. In 1926 this species had its maximum abundance in the Julsound. We found on the 18th of March 1926 already over 5000 cells per litre, and this number continued until the 10th of April, the only difference was that we now found the maximum number at a depth of 25 metres.

In 1927 it began to flower very early. It was taken as early as the month of March over the greater part of the Bank, but only in small numbers. It had a distinct maximum number of 31,000 cells per litre on the 22nd of March 1927 in the Romsdalsfjord, but also a smaller one, 6800 cells per litre, on the 28th of March out at Storeggen.

Silicoflagellata.

79) *Dictyocha fibula*, Ehr. This form was observed twice in the month of March out at the Bank, but only individual specimens were found.

80) *Distephanus speculum*, (Ehr.). This species occurred always in small quantities, its maximum number being 2—300 cells per litre. It was found scattered through the whole material.

Peridiniales.

81) *Ceratium arcticum* (Ehr.). This form was recorded from two stations at Storeggen, on March 16th and May 12th 1926. This species is a sure indication of the mixture of water from the East-Icelandic polar stream.

82) *C. bucephalum*, Cleve. This species was observed altogether nine times, but always individually both at Storeggen, at the Julsound, and on the Romsdals Bank. This one as well as the following species, with the exception of *C. longipes*, is to be considered the remnant from the rich *Ceratium*-plankton of the autumn. The *Ceratium*-species had not yet began to propagate to any great extent, and they were found at this time of year just as often in the deeper waterlayers as in the surface layers.

83) *C. furca* (Ehr.). This form was found in about twenty samples, as a rule individually, and usually at the inner part of the Bank.

84) *C. fusus* (Ehr.). Mostly single specimens of this form were observed in thirty-three samples.

85) *C. intermedium*, Jörg. This form was obtained in seven samples, most of them at Storeggen and the outer part of the Bank.

86) *C. lineatum* (Ehr.). This species was recorded from seventeen samples of which eight were taken in the Julsound and the Romsdalsfjord.

87) *C. longipes*, Bailey. This species occurred altogether in forty-eight samples taken at twenty-five stations. We found it so regularly by the 28th—29th of April 1926 that we may consider that it had begun to propagate, and later on there was a steady increase in the numbers. The samples of 50 cc. are too small to give a representative value of its appearance, but it seemed even at this time of year to be so evenly distributed that we may use an average calculation with care, although this as a rule is not very safe.

We thus get as an average value for its appearance in every samples from a depth of 1 to 25 metres:

28th—29th of April 1926	14	cells per litre
12th of May 1926	27	— —
1st—2nd of June 1926	85	— —
24th—25th of June 1926	82	— —

It first began to propagate at the outer side of the Bank, where we found about 200 cells per litre on the 2nd of June 1926, in a depth of 1 to 10 metres. Later on, on the 24th of June we found a maximum number of the same size in the Julsound.

88) *C. macroceros* (Ehr.). This occurred always singly and usually farthest out on the Bank. It was recorded from five samples.

89) *C. tripos* (Ehr.). This species was found in forty-five samples from twenty-six stations. At first it was only taken individually, but later on there was an increase in the numbers although the increase was not so rapid as that of *C. longipes*. The optimum-temperature for the latter was certainly lower. We can also take the average-appearance of *C. tripos* per litre which we got at a depth of 1 to 25 metres.

	At all the stations inclusively	At Storeggen
16th—18th of March 1926	5	0
28th—29th of April 1926	21	13
12th of May 1926	11	33
1st—2nd of June 1926	25	40
24th—25th of June 1926	51	47

When we take all the stations collectively we find that the increase up to the 1st of June is irregular probably on account of the limits of error of the method. But out at Storeggen we found a slow and regular increase.

90) *Exuviaella baltica*, Lohm. Individual specimens of this form were recorded. They may have occurred more frequently in reality than shown by the tables as they may have been overlooked.

91) *Ex. sp.* A somewhat larger species than the previous one occurred in some of the samples from the beginning of June 1926. It did not appear, however, in such numbers that time was taken to examine it closer.

92) *Dinophysis acuminata* (Clap. et Lachm.). This was rather scarce. Its maximum number in June 1926 in the Julsound was 280 cells per litre.

93) *Dinophysis acuta*, Ehr. Individual specimens of this form were recorded from Storeggen on the 29th of April 1926.

94) *D. norvegica*, Clap. et Lachm. This form was very scarce from March to May. In June 1926 it was taken in the Julsound up to 280 cells per litre.

95) *Diplopsalis lenticulata*, Bergh. In June 1926 it was caught fairly regularly, otherwise only individual specimens were found.

96) *Diplopelta bomba*, Jörg. This was only caught individually.

97) *Goniodoma Ostenfeldi*, Paulsen. This form too was only taken individually.

98) *Gonyaulax spinifera* (Clap. et Lachm.). Single individuals of this form were observed in March 1927.

99) *Gymnodinium Lohmanni*, Paulsen. This species, which otherwise multiplies quite numerously, particularly just after a diatom maximum, was found in thirty samples from seventeen stations, but in our material it did not play a conspicuous part. It occurred in greater numbers in the Julsound and in the Romsdalsfjord than farther out. The variations in its quantitative distribution lie for the greater part within the limits of error of the method.

100) *G. sp.* Under this nomenclature I have recorded some naked heterotrophe peridinians, which did not play any big part in the plankton, so that there was no reason to spend further time in identifying them.

101) *Minuscula bipes* (Paulsen). This small autotrophic species did not play any great rôle in the plankton during the spring. Its maximum number, 80 cells per litre, was found on the 1st of June 1926 in the Julsound.

102) *Oxytoxum diploconus*, Stein. This rare atlantic species was recorded three times from the outer part of the Bank, on the 9th of April 1926 and on the 28th of March 1927 in a depth of 40 to 75 metres. The specimens correspond with Stein's description, but are somewhat broader in proportion to the length.

103) *O. gracile* n. sp. Colourless, with thin cell walls. Ovate with acuminate back-end. Front rounded with a small, oblique point. Length 27—30 μ. Square diameter 15 μ. This new form belonging to the nannoplankton has been found

both on the west-coast of Norway as well as in the Skagerrack. In our material it was obtained in twelve samples from eight stations and in greatest numbers, namely 200 cells per litre at Storeggen on the 28th of March 1927, at a depth of one metre. But it was also taken close to the shore and even in the Romsdalsfjord.

Fig. 4. *Oxytoxum gracile.* $\frac{750}{1}$.

104) *Peridinium achromaticum*, Levand. This was only found individually.

105) *P. conicum* (Gran). This species was recorded three times but only individually.

106) *P. crassipes*, Kofoid. This species was observed in eight samples from seven stations but always individually.

107) *P. depressum*, Bailey. This form appeared as a rule individually. It was found in twenty-seven samples from nineteen stations.

108) *P. divergens*, Ehr. Only single specimens of this species were recorded.

109) *P. geminum*, Jörg. This species which is an autotrophic form, multiplied a little almost over the whole Bank in April 1926. Its maximum number, 400 cells per litre, was recorded at the Budground on the 9th of April 1926. This figure may be a little too high on account of the limits of error of the method.

110) *P. ovatum*, Pouchet. This was found in twenty-eight samples from twenty-one stations, mostly individually and very often at a depth of 10 to 25 metres.

111) *P. pallidum*, Ostenfeld. This species was recorded from seven samples from seven stations, but only individually.

112) *P. pellucidum*, Bergh. This was also only found individually in ten samples from seven stations.

113) *P. pyriforme*, Paulsen. This species was found once only.

114) *P. Steinii*, Jörg. This was obtained singly in six samples from five stations.

115) *P. sp.* Under this term are included small peridinians with a cell wall. No opportunity was afforded to determine the species under the counting process. As a rule the number was of no importance, but in some samples it was as high as 1200 cells per litre.

116) *Phalacroma rotundatum* (Clap. et Lachm.). During the investigation on the 28th of April 1926, this form appeared quite regularly all over the Romsdals Bank even though in numbers which lay on the border limit of the counting method. The same was the case in the Julsound but otherwise it only appeared individually.

117) *Ph. sp.* Another species, which was not determined, was found once at Storeggen on the 24th of June 1926.

118) *Podolampas palmipes*, Stein. Single specimens of this species were taken on the 22nd of March 1927 in the Julsound.

119) *Protoceratium reticulatum* (Clap. et Lachm.). This was rather scarce in June 1926, the time of year when it was taken in the Julsound.

120) *Torodinium robustum*, Kofoid. Single individuals of this species were found in eight samples from seven stations.

Infusoria.

121) *Amoeba sp.* In the samples from March 1927 an amoeba was observed, which attacked *Asterionella japonica* and partly enveloped its cells and assimilated them. Out at Storeggen more than 30,000 individuals per litre were found.

122) *Cyttarocylis denticulata*, Ehr. This species was found in thirty-six samples from twenty-two stations, but as a rule only individually, and rarely as many as 160 individuals per litre occurred. That number was obtained in the Julsound on the first of June 1926, at a depth of 10 metres, and in the Romsdalsfjord on the 22nd of March 1927, at a depth of 10 metres.

123) *C. norvegica*, Clap. et Lachm. This form was recorded from thirteen stations in twenty-five samples. It was more numerous in June than from March-May. The maximum number was about 200 individuals per litre.

124) *Laboea acuminata*, Leegaard. This was found scattered over the whole area. The maximum number, 320 individuals per litre, was found in a depth of 10 metres at the head of the Romsdalsfjord on the 22nd of March 1927. It seems to prefer the surface layers.

125) *L. conica*, Lohm. This species as a rule keeps to the surface, where it is not carried down to the depths by the movements of the waterlayers. It was recorded both near land and out at Storeggen. Its maximum number (1500 per litre) was found on the 16th—18th of March 1926 in the Julsound, and on 28th—29th of April 1926 out at Storeggen with a maximum number of 1040 individuals per litre. However, it never appeared in such great numbers that anything can be said with certainty about the quantitative variations of its appearance.

126) *L. constricta* (Meunier). This species, which never had living cells of algae in its interior, kept to the deeper waterlayers. In most cases only single specimens were found in every 50 cc. sample scattered through the whole material.

127) *L. crassula*, Leegaard. I am not quite sure about the limits of this species, but biologically it acted in the same manner as the previous species.

128) *L. emergens*, Leegaard. A few of this species were found scattered through the whole material. A maximum number of 200 individuals per litre was found outside Storeggen on the 28th of March 1927 at a depth of one metre.

129) *L. strobila*, Lohmann. This very characteristic species is symbio-trophic as *L. acuminata*, *L. conica*, and *vestita*. It keeps to the surface or a little below it. On the 22nd of March 1927 a maximum number of 680 individuals per litre

was recorded from the head of the Romsdalsfjord. It was otherwise found through the whole material.

130) *L. vestita*, Leegaard. This form along with *L. conica* was the most common of all the *Laboea*-species. In our material it reached a maximum number of 12—1300 individuals per litre out at the Bank from March-April 1926.

131) *Lohmanniella oviformis*, Leegaard. This is a heterotrophic species which appeared at almost every station and in every depth. Very often only one or a few specimens were found in the samples, but sometimes they were also found in greater numbers. On the 12th of May 1926, 820 individuals per litre were taken at Storeggen at a depth of one metre, and on March 28th 1927 they were found at a depth of 10 metres at the Budground with a maximum number of 1600 individuals per litre.

132) *L. spiralis*, Leegaard. This form was much more uncommon than the previous species, and as a rule it was only single individuals which were obtained from the samples. It was found in ten samples from nine stations.

133) *Mesodinium rubrum*, Lohmann. This species was found scattered through the whole material. On 16th—18th of March 1926 it had a very distinct maximum, 1200 individuals per litre, near land in the Julsound at a depth of one metre. It was found in the beginning of April over the whole Bank, but on the 28th—29th of April 1926 it had again a maximum of about 1000 individuals per litre, near land. From May-June there were a decrease in number. In March 1927 it had its maximum abundance (7—900 per litre) in the Romsdalsfjord. On the whole it is found during the spring in greater numbers near land than farther out.

134) *Ptychocylis urnula* (Clap. et Lachm.). This form was found scattered through the whole material mostly as single individuals in 50 cc. samples.

135) *Strombidium* sp. Single individuals of a not determined species were taken on Storeggen on the 24th of June 1926 at a depth of 40 to 75 metres.

136) *Tintinnopsis ventricosa* (Clap. et Lachm.). Single specimens of this form were obtained from March-April 1926. Out on the Bank at Station 49, up to 100 individuals per litre were found on the 9th of April 1926.

137) *Tintinnopsis sp.* Only single specimens were recorded.

138) *Tintinnus acuminatus*, Clap. et Lachm. This form was only taken individually from the Romsdalsfjord out to Storeggen at a depth of usually 25 to 75 metres.

139) *Woodania conicoides*, Leegaard. This symbiotrophic form was mostly taken in the surface layers from April-May. On the 12th of May 1926 its maximum number, 1200 individuals per litre was found at Storeggen.

140) *Infusoria cetera.* Under this term are included different mostly holotrichic Infusorians, which have not been identified owing to lack of time. In the present material these species play quite a subordinate part. The greatest numbers in a single sample were 200 per litre.

Discussion of the results.

It appears from the present investigations that outside the banks at Romsdalen an enormous reproduction of plankton-diatoms occurs on the one side close to the shore, and on the other out at Storeggen, where the waters from the Gulf Stream strike against the slope of the Bank-plateau. Gradually the masses of plankton from both sides merge together, so that a uniform, rich diatom-plankton appears over the whole Bank. Nevertheless a quantitative and a qualitative difference in the composition of the species is seen between the outer part of the Bank on the one side and the Romsdalsfjord including the Julsound on the other.

It is therefore most expedient to deal with the two phenomena separately and so the local plankton close to the shore is dealt with first.

I. The plankton development on the coasts of Romsdalen.

After five years investigations (1898, 1899, 1900, 1926, and 1927) we are now able to state that the development of the diatom-plankton during the spring begins in the latter part of March with *Skeletonema costatum*, *Chaetoceras sociale* and *Phaeocystis Pouchetii*. We must add the last named species because it is connected biologically with the diatoms. Shortly after the above species have begun to develop an increase of *Chaetoceras debile* takes place, so that that form becomes quite dominant. Besides this species we found a great many others chiefly neritic forms, both purely arctic species such as *Chaetoceras furcellatum*, *Achnanthes taeniata*, *Fragilaria oceanica*, *Thalassiosira hyalina* and comparatively southern forms such as *Chaetoceras constrictum*, *curvisetum*, *didymum* and *Willei*, *Ditylum Brightwellii* and *Lauderia borealis*. Between these extremes we find a series of species which require a medium temperature to reproduce — such as *Thalassiosira Nordenskiöldii* and *gravida*, *Lauderia glacialis*, *Coscinosira polychorda*, *Chaetoceras diadema*, *laciniosum* and *teres*, *Thalassiothrix nitzschioides*, *Coscinodiscus concinnus*, *Leptocylindrus danicus*, etc. On the whole we found almost every species which is recorded from the coast of Norway. The extreme arctic and southern species appear quite subordinate, perhaps with the exception of *Lauderia borealis*. Other species, which demand almost the same temperature as *Chaetoceras debile* are found in greater numbers, but the relation between them seems to vary from year to year. It seems to be characteristic for the coast of Romsdalen that *Chaetoceras debile* practically monopolises the plankton at this season. During the month of March 1898, a consecutive investigation was carried out from the Skagerrack to Trondhjem and I found the mass-production of it limited to the area outside Romsdalen. That year the most prominent species both in the Skagerrack and along the southwest coast of Norway was *Thalassiothrix nitzschioides* and not *Thalassiosira Nordenskiöldii* which I usually found other years. Everywhere else along the coast the more northern species dominate the plankton during March. In the Skagerrack

and at the south west coast *Thalassiosira Nordenskiöldii* is found along with the same secondary species excluding the pure arctic ones. At the Lofoten Islands it is *Skeletonema costatum*, *Chaetoceras sociale*, *Phaeocystis Pouchetii* which are most prominent, but also the arctic species *Chaetoceras furcellatum*, *Fragilaria oceanica*, *Achnanthes taeniata*, *Navicula Vanhöffeni*, and *Thalassiosira hyalina* occur in considerable numbers (Birgithe Ruud Föyn 1928). Also the more common species are found, such as *Chaetoceras debile*, *compressum*, *laciniosum*, *diadema*, *Coscinosira polychorda*, *Lauderia glacialis*, *Thalassiothrix nitzschioides* together with the oceanic species *Chaetoceras boreale* and *decipiens*, *Rhizosolenia alata* and *Nitzschia seriata.*

This diatom-plankton appears here as at the other places when the yearly temperature of the surface layers of the sea is at its lowest. In 1926 this was 3.5°—4° C., and in 1927, 4°—4.5° C. The temperature during the spring flowering in the Skagerrack is as a rule 0°—1° C., off Bergen (1922) 4°—4.5° C., and at the Lofoten Islands 3°—4° C.

We found the maximum number in the Skagerrack from February-March, off Bergen during the later half of March, at Romsdalen at the end of March and during the early part of April, and at the Lofoten Islands during the first half of April. At the same time the *Ceratium*-species have their yearly minimum along the whole coast.

The first maximum of the diatoms, which seems to be the only great maximum some years, disappears very rapidly because the diatom cells sink from the surface down to the depths where they are eaten up by animals to a great extent, mostly Copepods.

Other years a series of maxima may appear after each other as clearly shown by Marshall and Orr in Loch Striven. Similar conditions can prevail at the coast of Romsdalen, as we can see from the investigations at Ona lighthouse, 1900. In 1926 we found such a secondary maximum number in the Julsound (and very probably also in the Romsdalsfjord) about the 1st of June. The species may be partly the same as at the first maximum. Marshall and Orr found *Skeletonema costatum* was dominant both from March-April, in May and in November. In the months of March and April and on the 1st of June 1926 we found in the Julsound *Chaetoceras debile* dominating the plankton besides *Skeletonema costatum*, *Thalassiosira gravida*, and *Nitzschia seriata.*

The same species, which disappeared in April after a maximum number in March, reappeared in the latter half of May. As may be expected on account of the temperature which rises by this time to 6° C., and in the surface layers to 8° C., the relation between the secondary species had altered somewhat compared with the March-plankton. The species which had increased in number compared with the plankton from March-April were *Lauderia borealis*, *Leptocylindrus danicus*, *L. minimus*, *Rhizosolenia fragilissima*, *Thalassiosira bioculata* and the more oceanic species *Chaetoceras atlanticum* and *decipiens*, and *Nitzschia delicatissima* and *seriata.*

When we find several maxima following each other at the same place, we cannot explain it solely from the yearly periodicity of each separate species. The requirements of each separate species to such factors as temperature and salinity may decide which of them will happen to dominate the plankton. But the question of whether a rich diatom-plankton is going to develop must be determined by a factor independent of the life cycle of the species, and in the present case this factor is undoubtedly the supply of dissolved nutritive material. This hypothesis has been confirmed by all the later investigations (Birgithe Ruud 1926, Bigelow 1926, Marshall and Orr 1927, Gaarder and Gran 1927, Gran 1927, Birgithe Ruud Föyn 1928).

If we take it for granted that this interpretation is correct, we can divide the northern European coastal waters into three biological groups, between which we may expect to find all sorts of transitions.

1) Regions with a rich diatom-plankton throughout the whole season without any distinct change between maxima and minima, and in which an even supply of nutritive material from land or constant active circulation of nutritive material is available.

We have a very good example of such an area in the Limfjord, Denmark, according to Ostenfeld's investigation (1913[a] pp. 256—259). This fjord is surrounded by cultivated fields and the depth at Nyköbing, where Ostenfeld took his samples is only 7.5 metres. Vertical circulation during the greater part of the year might take place here owing to the bottom being heated up by the sun.

Ostenfeld's investigations extended through three years from the 2nd of May 1898 to the 14th of April 1901. The samples were collected every fortnight. The diatoms were by far the most predominant in comparison with the other plankton-algae, except in a very few instances.

Small numbers of diatoms were found:

21st of November 1898—21st of February 1899.
24th of May 1899.
22nd of July 1899.
21st of December 1899—3rd of March 1900.
21st of May 1900—22nd of June 1900.
6th of November 1900—4th of February 1901.

He found a constant winter minimum every year during the months of November or December until February, otherwise he found only three short minima during the spring or the late summer.

The predominant species were:

1898, May 2nd—18th, *Chaetoceras constrictum.*
May 18th—July 15th, *Ch. curvisetum.*
July 3rd—November 6th, *Ch. debile.*

1899, March 6th—21st, *Biddulphia aurita*, *Coscinosira polychorda.*
March 21st—May 6th, *Skeletonema costatum.*
June 6th—22nd, *Chaetoceras curvisetum.*
July 8th, *Ch. Schüttii*, *Ch. anastomosans.*
August 7th—23rd, *Ch. didymum.*
September 7th—November 7th, *Ch. debile.*
November 7th—December 6th, *Skeletonema costatum.*
1900, February 6th—March 23rd, *Biddulphia aurita.*
March 23rd—April 21st, *Chaetoceras sociale*, March 23rd *Lauderia glacialis*, April 21st *Chaetoceras debile*, *Rhizosolenia setigera.*
July 8th—25th, *Chaetoceras contortum* (*compressum*).
August 10th—23rd, *Ch. crinitum.*
August 23rd—September 7th, *Ch. curvisetum*, *Ch. didynmum.*
September 21st—October 22nd, *Ch. debile.*
1901, February 19th, *Biddulphia aurita.*
February 19th—March 5th, *Detonula confervacca.*
February 19th—April 14th, *Skeletonema costatum.*

The temporary interruptions in the development of the diatoms, which occurred some years from May to July, may be due to a stoppage in the supply of nutritive materials in the dry season, or they may be due to some other conditions, which we are prevented from considering. Otherwise the cycle is almost continuous from February when *Biddulphia aurita* began to flower in 1900 at a temperature below 0° C., to November or December. A succession of the most predominant species varying a little from year to year occurs, still with some characteristically common features e. g. the characteristic autumn maximum of *Chaetoceras debile.*

2) Regions with alternative maxima and minima during the whole season. The vertical circulation of nutritive material is barred for a greater part of the year, principally during the summer months when the surface layers with a low salinity get heated up. The supply of nutritive material from land takes place during the melting of the snow and during wet seasons.

Loch Striven is a typical example of such conditions according to Marshall and Orr. I have taken the liberty to represent a graphical grouping of their results (see fig. 5 pag. 52). The curves show how after each diatom-maximum the phosphates decreased or disappeared in the surface layers and at the same time they increased in the deeper water layers. We also see that there was an increase in the oxygen content owing to the photosynthesis of the diatoms. Twice, from the 2nd to the 7th of April and from the 31st of August to the 7th of September 1926 the increase of oxygen was quite remarkable, 2.2 cc. and 2.1 cc. respectively, or 0.44 and 0.3 cc. per litre in twenty four hours.

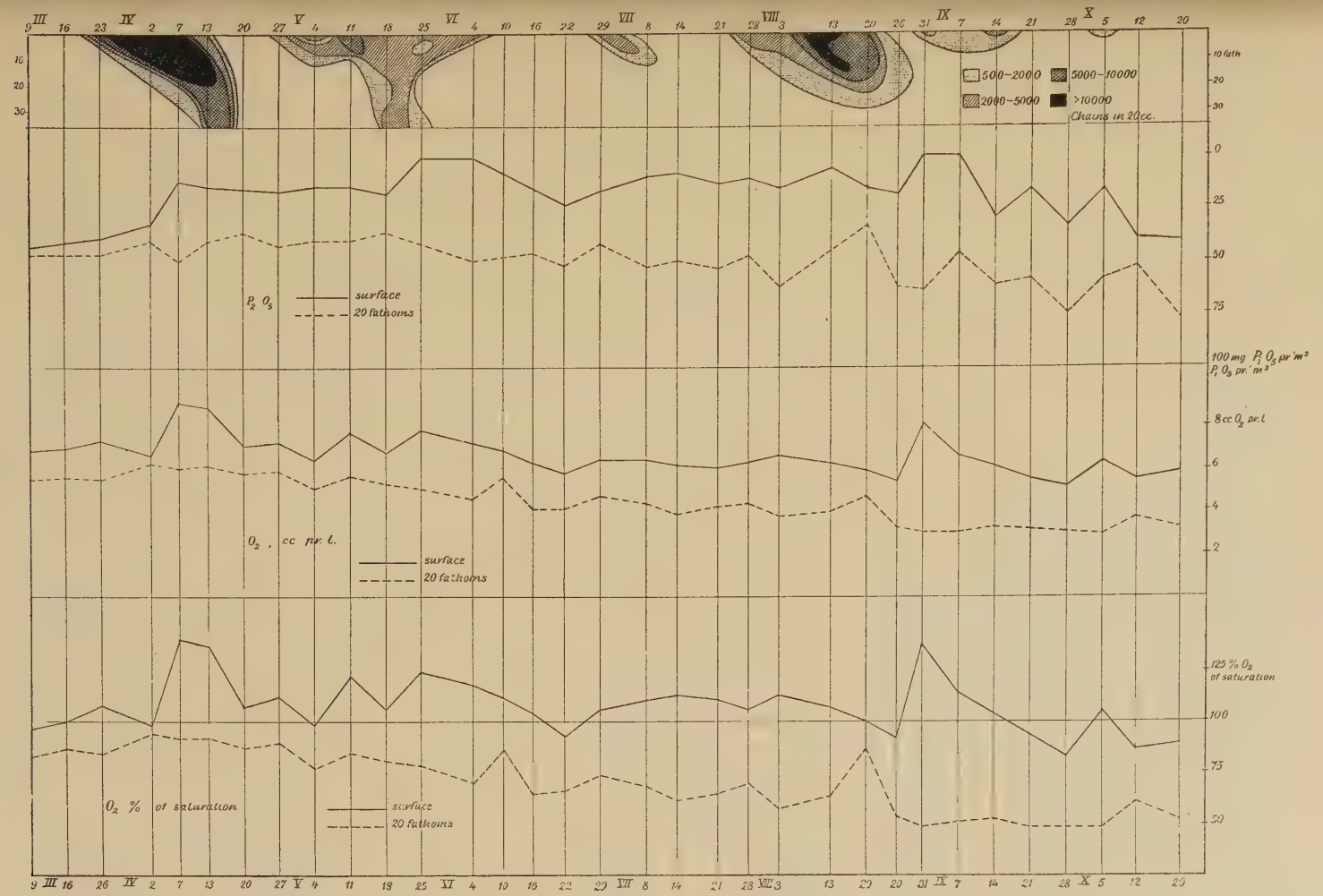

Fig. 5. Variations of the plankton diatoms, phosphate and oxygen content in Loch Striven 1926. From MARSHALL and ORR.

Marshall and Orr think that the content of the nutritive material in the surface layers somehow or other may be renewed by a mixture with the deeper water layers. Their graphs of the distribution of the water-density (σ_t, plate VII) show that vertical circulation by convection currents will hardly ever take place. The mixture of the water layers should therefore only occur by the action of the wind, when the surface layers are carried along and the reactionary currents bring the deeper water layers to the surface. Also, it is very probable that the nutritive materials are supplied from the shore after a wet period, particularly nitrogen as a result of nitrification in the soil. The essential and characteristic facts are that the nutritive material in the surface layers is used up so that the scarcity of these salts checks the development of the diatoms and also that the supply is not renewed continuously but only under certain conditions.

According to this type the plankton-development occurs along a great part of the Norwegian coast at any rate in certain years. This is particularly the case in the Oslofjord, where the first maximum of *Thalassiosira Nordenskiöldii* is succeeded by other maxima following each other very closely. We may come across a *Chaetoceras constrictum*-plankton in April, and a *Leptocylindrus danicus*-plankton in June and in the middle of the summer there may occur great numbers of such species as *Rhizosolenia faeröensis* or *Chaetoceras curvisetum*. And during the autumn in November, we may find a typical *Didymus*-plankton after Cleve's nomenclature (1896). At the coast of Romsdalen we came across examples of such series of maxima in 1900, and in 1926 a secondary maximum was present about the 1st of June. Other years, however, the plankton development may be more related to the following type.

3) Regions with one great spring maximum after the melting of the snow when the temperature in the surface layers of the water is at its lowest. Vertical circulation is utterly out of the question except probably locally and till certain depths when the minimum temperature occurs during the later winter months. During the summer from the end of April well into the autumn the *Ceratium*-species monopolise the plankton. Their minimum number occurs in March and after that time we find a slow, gradual increase. Later on the increase is more rapid up to September or October when the greatest number of individuals is reached.

The *Ceratium*-species must require less nourishment than the diatoms. This is evident by their slow multiplication. Their daily increase percentage in the Oslofjord during the summer may reach to something over 30 (Gran 1912), whilst diatoms such as *Chaetoceras curvisetum* can under favorable conditions have a daily increase of 360, a percentage that is about ten times as much.

One must also realise the physiological importance of the mobility of the *Ceratium*-species, which to a certain extent enables them to rise and sink vertically. During the summer of 1908 I was able to prove such vertical journeys daily in

the Oslofjord inside the narrow surface water layers. It would be an interesting question to investigate if, at other places where the surface layers are more voluminous, they are also able to accomplish vertical journeys to such an extent, that they are able to use nutritive salts at a depth of 30—40 metres.

In May 1912 I found in the North Sea that they had a tendency to collect in the zone between the lighter surface layers and the layers nearer the bottom with a higher salinity, preferably at about 30 metres. In any case their mobility will help to circulate a greater amount of the scanty nutritive material in the surface layers. Most of the plankton-diatoms on the other hand are quite incapable of movement and therefore absolutely dependent on the nutritive salts which are to be found in their immediate surroundings. They sink down to greath depths with the result that the surface layers are deprived of a great deal of their nutritive content. The most characteristic features within such regions are that during the spring, given favourable nutritive conditions, a short mass-production of diatoms (and sometimes *Phaeocystis*) will occur. During the summer there is such poor supply of nutritive salts in the surface layers that the rapid growing diatoms do not obtain enough nourishment to continue their constant normal increase, so that the slow growing and more easily contented *Ceratium*-species dominate the sea for the remainder of the season. Owing to the high temperature and the low salinity the surface layers are light, and the water can spread from the coast far out over the open sea, as was proved in 1900 (Hjort 1901) by the "Michael Sars"s expedition. The nutritive supply from land is distributed over a bigger area on that account, and the concentration near land therefore must be lowered.

The three types of development of the coastal plankton, which I have tried to distinguish from each other, show all possible transitions among themselves, and the marine currents, which carry the water columns from place to place, contribute to complicate the conditions still more (cf. Gran and Gaarder 1918). But common amongst all types are the great spring maxima, which owe their origin according to my theory to the rich supply of nutritive material from the land during the melting of the snow. This theory is upheld also by Bigelow and Birgithe Ruud Föyn. It will be possible to control this theory by following up these investigations, now that we have satisfactory methods for estimating the variation in the phosphates and nitrates.

II. The plankton-development at Storeggen.

The conditions of the plankton-development at Storeggen are more complicated than near land. In the Romsdalsfjord and at the Skerries we found associations of species, which for the greater part at any rate must be considered stationary, as Birgithe Ruud Föyn found to be the case at the Lofoten Islands. When the conditions for development are favourable, a nucleus of species will always be

present, which remains in the area either as resting spores or in some other way. At certain times some of the species will find more favourable conditions of existence than others, so that the composition of the plankton at the different seasons of the year is not the same qualitatively nor quantitatively. The conditions of life on the whole are therefore the only changeable factor we need take into account.

At Storeggen there is a constant motion of waters, it is therefore not only the conditions of existence which vary, but also the association of species which the body of water has carried with it from other parts of the sea, and we know already from the present investigation, which covers only two years, that great variations in the composition of species from year to year can occur.

The first question which suggests itself is where do the species come from which form the mass-production at Storeggen from March—April? They are on the whole neritic forms as they are at Vesterålseggen outside the Lofoten Islands. According to our knowledge of the direction of the current at these areas, they must either come along the Norwegian coasts from the northern part of the North Sea or in the Gulf Stream from the waters about Shetland. The species which were dominant at Storeggen in March 1926, *Chaetoceras debile*, *laciniosum* and *scolopendra* have such wide distribution that they might just as easily have come from either of the two regions. The surprising mass-occurrence of *Asterionella japonica* in March 1927 might make the question clearer.

According to Ostenfeld (1913[b]) this species, at the east-side of the northern Atlantic, has two centres of distribution, one at Shetland and the other in the English Channel and southern part of the North Sea. At Shetland this species has been recorded though scantily as early as from February—March, and it might be an all but obvious conclusion, that it had travelled this straight road. But we know on the other hand, that just in 1927 there had been a mass-immigration through Skagerrack even up to the Oslofjord where it was noticed as early as the 14th of February, and by the 28th of that month it occurred there as the most dominant species. It was also recorded from the west-coast of Norway as a dominating species in the beginning of March together with *Skeletonema costatum*. How early it had appeared here, I am unfortunately unable to say, but I do not see any reason which renders it impossible that it can have come to Storeggen in the current along the coast of Norway. We found on the other hand at Storeggen at the same time such a distinct Atlantic species as *Oxytoxum diploconus*, which indicates that water has come across from the Faroe-Shetland-Channel as well and we must probably allow for the possibility that the rich diatom-plankton at Storeggen has developed from germs which have arrived from both sides of the North Sea.

If we consider the germs have come in the Gulf Stream from waters about Shetland, they should not require more than fifteen days to arrive at Storeggen, because the rate of motion of the current at that distance according to Helland-

Hansen and Nansen (1916) is stated as 14 miles in twenty-four hours and the distance is $3^1/_2°$ or 210 miles.

The corresponding plankton which Mrs. Föyn found at Vesterålseggen at the beginning of April 1923 and 1926, and which seems to appear as a constant phenomenon there, must have a similar origin. Strange to say it was the *Skeletonema costatum* which dominated both years. The rate of motion of the current between Storeggen and Vesterålseggen is more difficult to calculate according to the data before us. In accordance with Krümmel (1911 p. 654) the rate of motion of the bulk of the current from the North Sea plateau to the Lofoten Islands, when all the whirls are taken into account is estimated to be 1 to 3 miles in twenty-four hours. But nearer the coastal bank the rate of motion rises up to 5 to 9 miles in twenty-four hours and at some places even twice that amount, particularly during the winter with the prevailing strong winds from the south-west. It is these greater rates of motion we have to take into account. With a rate of motion of 9 miles in twenty-four hours the bulk of water ought to take eight hundred and eighty eight hours to reach from Storeggen to Vesterålseggen ($5^1/_2°$) or one thousand two hundred and forthy-eight hours to reach from Shetland to Vesterålen.

The water which reaches Storeggen the last days of March should then have passed Shetland in the middle of March. The germs which develop along the Vesterålseggen about the 10th of April should have been at Shetland about the middle of February.

All the observations from the coasts of northern Europe show that *Skeletonema* at most places is the first of all the species to begin to reproduce after the winterrest, and I am greatly tempted to believe that *Skeletonema* develops off Shetland as early as February and that that is the reason why it reaches Vesterålseggen exactly at the time when the conditions to reproduce are most favourable, whilst the germs, which reach Storeggen in the month of March, have formed part of the plankton round about Shetland at a later time of its development, when a greater variety of species was present. In 1926 it was *Chaetoceras debile*, *laciniosum scolopendra*, etc., and in 1927 it was chiefly *Asterionella japonica*. It should be possible to control this hypothesis at later investigations.

The second question is why the plankton begins to reproduce just at the edge of the shelf and later on floats over the bank and why the plankton appears at certain times and disappears after a few weeks. Birgithe Ruud Föyn has come to the conclusion that it is the vertical currents, which are formed when the Atlantic current is pressed towards the edge of the shelf, carrying dissolved nutritive materials from the depth up to the surface layers, which are the causative factor. She also concieves the possibility that deep running water from the polar current might be carried up to the surface. Bigelow gives a similar explanation with regard to the plankton development at the George's Bank outside the Gulf of Maine and I cannot put forward any other explanation. The hydrographical tables from

Station 104, 1st of March 1927, also show that the density of the water at the time in question is uniform from the surface down to as far as the observations go, 150 metres ($\sigma_t = 27.52—27.56$). All the conditions for vertical circulation are present at the beginning of the month, but by the end of the month when the plankton has developed we find over the edge of the shelf (Station 110) a more than 10 metres thick lighter surface water layer (at 1 to 10 metres $\sigma_t = 27.05—27.08$, at 25 metres, 27.26) which prevents the vertical circulation up to the surface. We also get from this a possible explanation of the rapid disappearance of the plankton at Storeggen after the great spring flowering.

III. The quantity of the production.

The increase of oxygen in the surface layers (1 to 10 metres) from the beginning (cf. table 5 p. 28) to the end of March, that is to say in the course of four weeks, was 0.4 to 0.9 cc. per litre. The low value, in a depth of 10 metres, 0.28 cc. per litre, at the station nearest land (in the Julsound) is a consequence of the water being supersaturated already by March 2nd with oxygen. We get on an average in one metre an increase of 0.74 cc. per litre and in 10 metres 0.62 cc. per litre. These values are of the same order of size as the increase during the great spring maxima off Bergen in 1922 (Gran 1927) and at the Lofoten Islands (Birgithe Ruud Föyn 1928). Outside Romsdalen the values in the surface layers are a little lower, but the difference probably lies within the limits of error of the method, specially as we cannot with certainty be sure to have struck the moment when the concentration of oxygen was at its maximum.

The increase of oxygen in the surface layers in the waters outside the coast of Norway lies on the whole considerably lower than what Marshall and Orr found at Clapochlar in Loch Striven. Here the increase in the surface layers from the 2nd to the 7th of April 1926 was 2.2 cc. per litre. The number of plankton diatoms was also correspondingly greater. The most dominating species, *Skeletonema costatum*, occurred during the first maximum with a number of more than 25000 chains per 20 cc. If we calculate the number of cells in a chain of *Skeletonema* as 16, and this is surely a low calculation, the number is still 20 millions cells per litre. Such large quantities are found only quite exceptionally at the Norwegian coast (at Dröbak 1st of March 1908). Usually only one tenth of the above number is found.

But there is another difference which is striking. The increase of oxygen in Loch Striven during the great maximum at the beginning of April is by this time less at a depth of 5 fathoms than in the surface layers, namely only 0.8 cc per litre and hardly perceptible at a depth of 10 fathoms. During the productive period at the end of August, when the oxygen content in the surface layers rose

2.1 cc. in a week, the increase at a depth of 5 fathoms was scarcely noticeable. This must indicate that the surface layers at that time were less transparent.

Outside Romsdalen the increase in the oxygen content at the two stations farthest out was also limited to the surface layers down to a depth of 10 metres, but at the three stations nearest land there was a marked and sometimes a great increase as low down as 75 metres. The increase of oxygen down to such great depths must be due to the surface layers being pressed together, whilst it is quite impossible that sufficient light penetrates so deeply and effects photosynthesis. But still, this great increase also in the deeper water layers must be taken into account when we look for the minimum value of the total production. If as a precautionary measure we calculate the increase at a depth of one metre representing a water-column of 0 to 1 metre, then the increase in a depth of 10 metres, represents a water-column of 1 to 10 metres, etc. we get the following values for the total production in four weeks per square metre of surface.

	Storeggen (Station 110) 0 to 10 metres	The Bank (Station 111) 0 to 10 metres	The Budground (Station 112) 0 to 75 metres	The Bud deep (Station 113) 0 to 75 metres	The Julsound (Station 114) 0 to 75 metres
Litres of Oxygen....	9.23	6.75	21.68	31.09	21.42
Grammes of Oxygen..	13.19	9.62	30.98	44.43	30.47
Grammes of Glucose..	12.37	9.04	29.05	41.66	28.57

For the waters off Bergen I calculated (Gran 1923) a minimum value of 14 grammes of glucose per square metres of surface over an area of 40 miles wide from the shore. Accordingly we found at Romsdalen a considerable higher value close to land, but not so high a value farthest out on the Bank. The maximum was just outside the Skerries.

Resumé.

I) At Aukra whaling station outside Romsdalen water samples for quantitative plankton investigation were collected from nine cruises in the motor-boat "Morild", from March to June 1926 and in March 1927. The water samples were centrifuged. Simultaneously, determinations of the temperature, salinity, oxygen content and at the last cruise also of P_H were carried out at the same depths (1, 10, 25, 40 and 75 metres). The observations were taken from five fixed stations.

1) Inside the Skerries (in the Julsound).
2) Just outside the Skerries (in Bud-dypet, 5′ NNW. of the Björnsound).
3) At the Budground (the shallowest part of the Bank, 17′ NW. of the Björnsound).
4) At the middle of the outer part of the Bank (32′ NW. of the Björnsound).
5) At Storeggen (46′ NW. of the Björnsound).

During some cruises observations were taken a little outside Storeggen, 51′ NW. of the Björnsound. On the 22nd of March 1927 two more observations were taken at the following stations:

6) In the middle of the Romsdalsfjord abreast of Molde.

7) At the head of the Romsdalsfjord.

II) The plankton was quantitatively very poor at the beginning of March both years. The increase began with *Skeletonema costatum*, *Chaetoceras sociale* and *Phaeocystis Pouchetii*. In the last part of March the characteristic spring maximum of diatoms appeared both years, at first close to the shore and about the same time out at Storeggen, and later on the two maxima merged into each other spreading over the whole Bank. The diatoms had almost disappeared in the whole investigated area by the end of April. About the 1st of June 1926 a new maximum of diatoms appeared but only close to the shore, in the Julsound, and in smaller quantities at the nearest station on the Bank.

III) The plankton in the Julsound and in the Romsdalsfjord consisted both years in March of the same species. The same association of plankton was found at the same place in March 1898, 1899, and 1900 in accordance with observations not yet published, cf. page 11. Every year the most dominnt species was *Chaetoceras debile*, cf. page 11 and tables VI, XIV, XXXIX, XLI, and XLVI. The predominant part of the observed species was neritic forms and must be considered as stationary. Some are distinctly arctic, but these play a subordinate rôle.

IV) The plankton, which developed at Storeggen and spread from there over the Bank, consisted also chiefly of neritic species. Some of them were the same as those found near land and thus had two local separated maxima to begin with. Other species appeared only or chiefly out at Storeggen. The most prominent species out at Storeggen in March 1926 were: *Chaetoceras debile*, *laciniosum*, and *scolopendra* and also *Thalassiosira gravida*. In 1927 *Asterionella japonica* dominated the area entirely, with a maximum number of as much as one and a half million cells per litre.

V) The *Ceratium*-species had their minimum number in March, but in the course of the spring a slow increase in the numbers occurred. The average frequency of *Ceratium tripos* on the 16th—18th of March at a depth of 1 to 25 metres was 5 cells pr. l. On the 24th—25th of June it had increased up to 51 cells per litre. If we take *Ceratium longipes* in the same way we found on the 28th—29th of April 14 cells per litre and on the 24th—25th of June, we found 82 cells per litre.

VI) The development at the coast of Romsdalen resembled closely that at the Lofoten Islands described by Birgithe Ruud Föyn 1928, and from the Gulf of Maine described by Bigelow (1927). At both places the development of the plankton began close to the shore just after the melting of the snow, and both authors agree that the most natural explanation is that the development of the plankton is stimulated by the supply of dissolved nutritive materials, which are

carried out to sea by the rivers at that time of year in greater concentration than at any other time (cf. Braadlie 1924). The most natural explanation for the development of the plankton at Storeggen as well as at Vesterålseggen outside the Lofoten Islands, and at George's Bank outside the Gulf of Maine, is that it is conditioned by the nutritive salts, which are carried to the surface from the depths by the vertical circulation formed when the current strikes the steep sides of the banks. The species which developed at the edge of the shelf must therefore come from the northern part of the North Sea as scattered cells with the current (cf. p. 55 about *Asterionella japonica*).

VII) If we now compare the results of the investigations from other regions, first of all that of Marshall and Orr from Loch Striven (1927), we can put forward the following three principal types for the yearly development of the plankton in the temperate coastal waters.

1) A rich and somewhat even supply of nutritive materials from land during the whole season and an active circulation of the available nutritive salts. The diatoms occur in great numbers from early spring to late autumn and dominate over all the other plankton algae. As an example may be considered the Limfjord according to Ostenfeld's investigation (1913[a]).
2) The supply of nutritive material from land is often rich but irregular. The mixing of the surface layers and the deeper water layers by vertical circulation can only take place intermittently. The diatoms develop in great masses and disappear when the nutritive materials in the surface layers are used up, so that the maxima and the minima change several times in the course of the year. Example: Loch Striven.
3) A rich supply of nutritive material during the spring with a minimum-temperature. Later on the food supply is more scarce. During the whole of the summer the vertical circulation is out of the question, because there is always a great difference between the density of the surface layers and the deeper water layers. Early in the spring a mass-production of diatoms occurs, otherwise *Ceratium*-species occur all the year round with maxima in the autumn. Owing to their smaller rate of multiplication (about one tenth that of the diatoms under similar circumstances) and by their mobility, these species are better adapted to utilise the minimum-concentration of the nutritive salts. As an example: The west-coast of Norway in most years.

VIII) On account of the increase in the oxygen content during March 1927, we found a minimum value for the production of organic substances during the spring-maximum of the diatoms at the Romsdals Bank per square metre of surface, calculated as glucose 9,04—41.66 grammes with a maximum just outside the Skerries. On the west-coast of Norway the corresponding value has previously been calculated on an average of 14 grammes for the Baltic current up to 40′ from the

shore. In Loch Striven the production in the surface layers can be several times greater, namely up to 2.2 cc. oxygen per litre in five days, corresponding to 2.95 grammes of sugar per cubic metre in five days or 0.59 grammes of glucose per cubic metre in twenty-four hours. Here, however, on the other hand the production is limited to a narrower surface layer. The density of the plankton according to Marshall and Orr's investigations can be estimated to be at least ten times as great as outside the coast of Norway.

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Tables.

Tabel I. 1926. St. 35. March 16th. 5 a.m. 48′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.71	..	7.70	7.81	8.21
Salinity	34.72	34.78	35.16	35.19	35.30
σ_t	27.26	..	27.46	27.48	27.50
Number of cc examined	50	50	50	50	50
Halosphæra viridis	..	..	..	..	20
Nitzschia delicatissima	..	..	40	..	..
Paralia sulcata	..	560	..	..	..
Rhizosolenia alata	..	..	20	..	..
— fragilissima	20	..	..	..	..
Thalassiosira bioculata	..	40	20	60	40
— decipiens	40	..	20	..	..
— gravida	20	20	..	..	..
Skeletonema costatum	200	80	..	..	..
Distephanus speculum	..	20	20	..	..
Ceratium arcticum	..	..	20	..	..
— fusus	..	..	..	20	20
Peridinium ovatum	..	20	..	..	..
Laboea emergens	..	..	20	..	..
Lohmanniella oviformis	20	20	..	..	..
Mesodinium rubrum	60	..	..	..	..
Infusoria cetera	20	..	..	..	..

Tabel II. 1926. St. 36. March 16th. 32′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	5.21	5.31	5.70	5.81	6.41
Salinity	34.00	34.05	34.29	34.42	34.70
σ_t	26.88	26.90	27.05	27.13	27.29
Number of cc examined	50	50	50	50	50
Chaetoceras laciniosum	160	..	..	..	..
Nitzschia Closterium	20	..	..	..	..
— delicatissima	..	..	..	..	60
Pleurosigma affine	..	..	..	20	..
Skeletonema costatum	820	740	460	220	2560
Thalassiosira decipiens	140	..	60	20	200
Thalassiothrix nitzschioides	..	100	..	..	..
Distephanus speculum	..	..	..	20	..
Ceratium furca	..	40	..	..	..
— fusus	20	..	20	..	..
— longipes	..	40	..	..	..
— tripos	20	..	..	..	..
Diplopsalis lenticula	..	..	..	20	..
Peridinium conicum	20	..	..	..	..
— depressum	..	..	..	20	..
— divergens	..	20	..	..	..
— Steinii	20	..	..	..	..
Laboea emergens	..	..	20	20	20
Lohmanniella oviformis	100	..	20	..	80
Tintinnopsis sp.	..	..	..	20	..
Nauplii	..	20	..	..	..
Rhizosolenia semispina	20	..	..	..	..

Tabel III. 1926. St. 37. March 16th. 2.30 p.m. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	5.2	5.3	5.7	6.4	7.0
Salinity	33.13	33.13	33.26	33.60	33.96
σ_t	26.62	26.62	26.72	27.00	27.29
Number of cc examined	50	50	50	50	50
Actinocyclus Ehrenbergii	..	..	..	20	..
Actinoptychus undulatus	..	..	..	..	20
Chaetoceras convolutum	..	60	..	..	..
Coscinodiscus radiatus	..	..	..	20	..
Navicula gelida var.	:	..	..	20	..
Nitzschia delicatissima	..	..	..	20	..
Rhizosolenia alata	..	20	..	..	..
Skeletonema costatum	100	..	160	220	260
Thalassiosira decipiens	40	20	160	20	..
Thalassiothrix nitzschioides	..	..	100	..	..
Distephanus speculum	..	..	..	..	20
Ceratium fusus	..	20	..	20	..
— lineatum	..	..	20	..	..
— tripos	..	..	40	..	..
Dinophysis acuminata	20	20	..	..	..
Minuscula bipes	20	20	..	..	..
Peridinium ovatum	..	..	20	..	..
— pellucidum	..	20	..	..	..
— sp.	20	..	..	..	..
Dinophysis norvegica	..	..	..	20	..
Codonella sp.	..	..	..	..	20
Laboea conica	20	..	..	..	..
— constricta	20	..	20	..	..
— crassula	20	..	..	..	..
— emergens	..	..	20	..	..
Lohmanniella oviformis	80	60	80	..	..
Mesodinium rubrum	180	40	..	..	..

Tabel IV. 1926. St. 38. March 16th. 5.15 p.m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	4.0	4.1	4.1	4.2	4.5
Salinity	33.13	33.17	33.24	33.35	33.46
σ_t	26.32	26.35	26.40	26.48	26.53
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	..	..	20	..	..
Asteromphalus heptactis	..	..	20	..	..
Chaetoceras debile	..	100	..	..	..
— decipiens	..	..	..	100	..
Coscinosira polychorda	20	..	..	..	..
Gyrosigma fasciola	..	..	..	..	20
Navicula gelida var.	..	20	..	..	..
Nitzschia Closterium	..	..	20	..	..
Rhizosolenia alata	..	..	..	20	..
— semispina	..	..	..	20	..
— setigera	..	..	..	..	20
Skeletonema costatum	200	140	160	120	760
Thalassiosira decipiens	120	20	..	..	40
— Nordenskiöldii	..	20	..	..	..
Thalassiothrix nitzschioides	60	..	40	40	160
Ceratium furca	..	20	20	..	..
— fusus	20	..	..	20	..
— longipes	..	..	..	..	20
— tripos	..	20	..	..	..
Peridinium sp.	20	20	20	..	..
Cyttarocylis denticulata	20	..	..	..	20
Laboea conica	..	20	..	..	..
— constricta	..	20	..	..	..
— crassula	..	..	..	20	20
— strobila	20	..	..	..	..
— vestita	100	20	..	..	..
Lohmanniella oviformis	100	140	..	20	..
Mesodinium rubrum	280	60	60	..	..

Tabel V. 1926. St. 42. March 18th. Julsund.

Depth	1	10	25	40	75
Temperature	3.7	3.8	4.1	4.2	5.5
Salinity	32.94	32.95	33.17	33.26	33.73
σ_τ	26.20	26.21	26.34	26.40	26.63
Number of cc examined	10	10	10	50	50
Eutreptia Lanowii	100	..	..	..	..
Bacterosira fragilis	400	..	..	..	..
Biddulphia aurita	200	..	..	..	..
Chaetoceras boreale	..	..	200	..	..
— compressum	2500	1600	..	..	..
— convolutum	..	200	..	..	..
— decipiens	..	500	..	..	..
— debile	115100	76500	8000	1740	..
— diadema	400	1600	..	..	..
— laciniosum	1800	1000	..	..	..
— scolopendra	5800	18000	..	..	..
— sociale	>200000	64300	22900	980[1])	520[1])
Coscinodiscus centralis	..	..	100	..	..
— radiatus	..	..	..	20	20
Coscinosira polychorda	800	400	..	20	..
Eucampia groenlandica	300	..	..	..	..
Lauderia glacialis	..	400	..	..	..
— borealis	300	..	..	40	..
Leptocylindrus minimus	..	..	..	60	..
Nitzschia delicatissima	200	1100	..	..	..
Skeletonema costatum	621400	364100	96700	57160	1700
Thalassiosira decipiens	..	..	..	40	20
— gravida	..	400	..	..	20
— Nordenskiöldii	1700	400	300	120	20
Thalassiothrix nitzschioides	5800	2600	900	800	600
Ceratium buccephalum	..	..	..	20	..
— furca	..	..	100	..	..
Distephanus speculum	..	..	100	..	..
Laboea conica	..	1800	100	..	..
— constricta	..	..	..	20	..
— vestita	100	200	..	..	..
Lohmanniella oviformis	200	..	..	20	..
— spiralis	..	..	100	..	..
Mesodinium rubrum	1200	400	..	..	..
Infusoria cetera	100	..	..	..	..

[1]) with spores.

Tabel VI. 1926. St. 43. March 26th. 2.30 p.m. Julsund.

Depth	1	10	25	40	75
Temperature	3.72	3.92	4.04	4.35	5.56
Salinity	32.66	33.12	33.19	33.26	33.98
σ_t	25.98	26.33	26.37	26.38	26.82
Oxygen, cc pr. l	8.30	7.23	7.07	6.70	6.56
— saturation %	112.5	98.8	96.9	92.7	93.6
Number of cc examined	10	10	10	50	50
Chaetoceras boreale	..	..	..	220	..
— compressum	..	..	1000	..	..
— convolutum	..	..	200	..	..
— curvisetum	..	600	600	..	..
— debile	395500	102500	106700	3140	..
— decipiens	5750	1200	700	..	..
— diadema	..	..	..	1720	..
— laciniosum	7500	3300	2000	640	..
— scolopendra	3750	800	1000	..	..
— simile	750	..	..	..	..
— sociale (spores)	7750	19900	15400	13320	1860
Coscinosira polychorda	..	1200	1000	180	..
Eucampia groenlandica	..	200	..	..	..
Fragilaria oceanica	..	2600	..	..	..
Lauderia borealis	..	600	..	340	..
— glacialis	..	..	200	140	..
Leptocylindrus danicus	..	..	..	120	..
— minimus	1250	..	..	..	..
Navicula gelida var.	..	100	400	20	..
Nitzschia Closterium	..	100	100	..	..
— delicatissima	2500	400	..	40	..
— seriata	250	400	..	20	..
Skeletonema costatum	454250	171100	92000	30320	540
Thalassiosira decipiens	..	1600	1200	40	..
— gravida	2750	1300	..	..	..
— Nordenskiöldii	3500	3600	500	1800	20
Thalassiothrix nitzschioides	3500	5500	600	1180	..
Distephanus speculum	..	100	..	20	20
Ceratium fusus	..	100	..	..	..
Goniodoma Ostenfeldi	..	100	..	..	..
Gymnodinium sp.	..	..	..	20	..
Peridinium pellucidum	..	..	100	..	..
— sp.	..	..	100	..	..
Lohmanniella oviformis	..	100	200	..	100
Mesodinium rubrum	..	100	..	..	..
Infusoria cetera	..	..	..	20	..

Tabel VII. 1926. St. 44. March 26th. 5 p.m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	4.43	4.05	4.20	4.46	5.53
Salinity	33.15	33.19	33.26	33.35	34.14
σ_t	26.30	26.37	26.40	26.45	26.96
Oxygen, cc pr. l	7.07	7.38	7.24	6.91	6.57
— saturation %	98.0	100.9	100.7	97.5	93.9
Number of cc examined	10	10	25	50	50
Chaetoceras compressum	..	300	..	..	..
— debile	7400	35200	1720	..	..
— laciniosum	1200	..	..	..	..
— scolopendra	700	300	..	..	..
— sociale (spores)	400	1200	240	80	60
Coscinosira polychorda	..	600	..	..	..
Lauderia glacialis	..	100	..	20	..
Navicula gelida var.	100	..	..	..	..
Nitzschia Closterium	100	..	..	..	40
Skeletonema costatum	112200	45700	5200	3520	1560
Thalassiosira decipiens	..	..	..	..	40
— Nordenskiöldii	500	500	..	20	..
Thalassiothrix nitzschioides	1000	600	..	60	80
Thalassiosira gravida	200	..	..	..	..
Dictyocha fibula	100	..	..	..	..
Distephanus speculum	..	..	40	..	20
Ceratium tripos	..	..	..	20	..
Gymnodinium Lohmanni	..	..	40	..	..
Laboea crassula	..	..	120	..	20
— vestita	..	300	..	..	..
Lohmanniella oviformis	..	400	..	..	100
Mesodinium rubrum	..	200	40	..	..

Tabel VIII. 1926. St. 45. March 26th. 8 p.m. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	4.06	4.09	4.05	4.08	5.43
Salinity	33.21	33.26	33.30	33.33	33.98
σ_t	26.37	26.41	26.44	26.47	26.84
Oxygen, cc pr. l	7.29	7.22	7.12	7.04	6.43
— saturation %	99.7	99.0	97.7	96.7	92.6
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	20	..	..	..	..
Chaetoceras compressum	400	..	..	180	..
— constrictum	40	..	..	..	..
— debile	1500	840	980	..	..
— laciniosum	380	200	80	..	..
— scolopendra	80	..	420	..	..
Coscinosira polychorda	..	..	..	20	..
Lauderia glacialis	..	100	..	20	..
Navicula gelida var.	..	20	20	..	..
Nitzschia Closterium	20	..	..	..	..
Rhizosolenia alata	..	..	..	20	..
Skeletonema costatum	28100	23700	20200	58640	460
Thalassiosira decipiens	40	..	..	..	..
— Nordenskiöldi	..	80	80	..	..
Thalassiothrix nitzschioides	120	100	120	60	..
Distephanus speculum	20	40	40	..	..
Ceratium furca	20	..	..	..	..
— fusus	..	20	..	..	..
— longipes	20	20	..	..	..
Peridinium crassipes	..	..	..	20	..
— sp.	20	20	..	..	..
Torodinium robustum	..	..	20	..	..
Ceratium tripos	..	..	..	40	..
Laboea conica	80	..	..	..	..
— crassula	40	..	20		..
— strobila	40	..	..	..	..
— vestita	1220	520	20	..	..
Lohmanniella oviformis	60	20	120	..	..
Mesodinium rubrum	120	20	140	..	..
Infusoria cetera	..	..	60	..	..

Tabel IX. 1926. St. 46. March 27th. 50.5′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.19	6.27	7.00	7.26	8.11
Salinity	34.43	34.51	34.97	35.12	35.34
σ_t	27.10	27.15	27.29	27.39	27.54
Oxygen, cc pr. l	7.25	7.17	6.37	6.30	6.27
— saturation %	105.4	104.8	94.8	94.5	95.9
Number of cc examined	10	50 (10)	50	50	50
Asterionella japonica	1500	500	..	..	..
Biddulphia aurita	..	200	..	..	..
Chaetoceras atlanticum	..	..	..	..	60
— boreale	1500	700	..	..	..
— compressum	1800	7700	..	..	..
— constrictum	9200	22600	..	..	..
— convolutum	800	800	..	..	..
— curvisetum	1600	1900	..	..	..
— debile	309000	322600	240	380	..
— decipiens	..	800	..	..	..
— diadema	21000	36800	..	..	..
— laciniosum	197800	201900	220	2100	..
— scolopendra	21000	24300	..	..	..
— simile	400	..	..	..	..
— teres	9600	11500	..	60	..
Coscinosira polychorda	800	..	..	..	..
Leptocylindrus danicus	5100	3400	..	120	..
Lauderia glacialis	400	600	..	20	..
Navicula gelida var.	3700	3300	..	80	..
Nitzschia delicatissima	400	900	..	200	400
— seriata	5600	4800	60	80	..
— Closterium	..	..	20	40	20
Rhizosolenia alata	..	100	..	..	20
— fragilissima	..	..	..	..	60
— semispina	2100	2200	..	120	..
Skeletonema costatum	1800	7000	..	480	920
Thalassiosira decipiens	200	..	..	..	..
— gravida	30100	29100	200	620	..
— Nordenskiöldii	7900	10200	..	80	..
Thalassiothrix longissima	100	..	..	20	..
Distephanus speculum	200	300	..	..	..
Ceratium bucephalum	..	20	..	..	..
— fusus	..	20	..	..	..
— lineatum	..	20	..	..	..
— tripos	..	40	..	..	..
Dinophysis norvegica	..	40	..	..	..
Peridinium depressum	..	20	..	..	..
— ovatum	..	20	..	..	
Laboea vestita	..	200	..	..	..
Lohmanniella oviformis	800	400	..	..	..

Tabel X. 1926. St. 47. April 9th. 6 a.m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	4.46	4.44	4.41	4.38	5.56
Salinity	33.08	33.06	33.12	33.12	34.16
σ_τ	26.23	26.22	26.27	26.27	26.96
Oxygen, cc pr. l.	7.94	7.93	7.91	7.45	6.56
— saturation %	110.1	110.0	109.7	103.4	93.6
Number of cc examined	5 (50)	5	..	5	50
Asterionella japonica	..	800	..	400	40
Chaetoceras boreale	60	..	..	..	..
— compressum	..	800	..	6000	..
— constrictum	2800	1000	..	4000	..
— convolutum	400	400	..	200	..
— curvisetum	..	400	..	..	..
— debile	110600	81200	..	142600	4080
— decipiens	..	600	..	600	..
— diadema	1600	9000	..	8000	..
— furcellatum	..	2400	..	..	..
— laciniosum	8000	2800	..	11600	..
— scolopendra	..	..	..	4000	..
— sociale (spores)	..	..	..	..	160
— teres	400	400	..	600	..
Coscinodiscus radiatus	..	..	..	..	20
Coscinosira polychorda	200	800	..	..	40
Lauderia glacialis	400	200	..	800	100
Leptocylindrus danicus	3000	600	..	..	..
— minimus	..	1600	..	..	..
Navicula gelida var.	1000	400	..	600	100
Nitzschia delicatissima	..	..	..	600	..
— seriata	200	800	..	400	20
Rhizosolenia semispina	..	..	..	200	40
Skeletonema costatum	571500	387800	..	2224000	5080
Thalassiosira gravida	2600	1200	..	800	140
— Nordenskiöldii	4200	3400	..	5600	120
Thalassiothrix nitzschioides	1400	..	..	..	80
Distephanus speculum	..	..	..	..	20
Ceratium furca	20	..	..	..	..
— lineatum	20	..	..	..	..
— longipes	60	..	..	..	..
— tripos	40	..	..	..	..
Dinophysis acuminata	..	400	..	..	..
Gymnodinium Lohmanni	40	200	..	..	..
— sp.	800	..	..	..	..
Peridinium depressum	20	..	..	..	..
— geminum	140	..	..	..	..
— ovatum	20	..	..	..	..
— pallidum	20	..	..	..	..
— pellucidum	200	400	..	200	..
— sp.	200	1200	..	..	20
Phalacroma rotundatum	200	..	..	..	..
Laboea conica	60	400	..	..	..
— constricta	..	..	..	..	20
— crassula	..	..	..	200	20
— strobile	60	..	..	..	..
— vestita	..	..	..	..	100
Lohmanniella oviformis	..	..	..	..	40
Mesodinium rubrum	200	200	..	..	..

Tabel XI. 1926. St. 48. April 9th. 9.30 a.m. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	4.66	4.62	4.65	4.91	6.32
Salinity	33.40	33.39	33.49	33.75	34.65
σ_t	26.49	26.48	26.56	26.72	27.25
Oxygen, cc pr. l.	7.61	7.70	7.46	6.82	6.42
— saturation %	106.0	107.1	106.3	95.8	94.3
Number of cc examined	5	5	25	40	50
Actinocyclus Ehrenbergii	..	..	..	..	20
Asterionella japonica	11000	3200	11400	375	..
Biddulphia aurita	200	..	40	..	..
Chaetoceras atlanticum	600	..	..	..	..
— boreale	800	800	840	425	..
— breve	..	800	..	175	..
— compressum	5400	7800	1920	275	..
— constrictum	26800	16800	2600	4200	..
— curvisetum	..	2200	280	175	..
— debile	187400	144600	176800	123200	200
— decipiens	..	..	..	425	..
— diadema	30800	11400	2800	1925	..
— laciniosum	8400	2000	1040	675	..
— scolopendra	15600	800	560	50	..
— sociale (spores)	44000	..	..	250	..
— teres	1600	1600	640	425	..
Coscinodiscus concinnus	..	..	..	125	..
Coscinosira polychorda	..	..	40	75	..
Guinardia flaccida	..	..	80	..	..
Lauderia glacialis	800	1000	320	125	..
Leptocylindrus danicus	11800	8600	2760	..	..
Navicula gelida var.	3600	3200	3520	1525	20
Nitzschia Closterium	..	200	..	..	..
— delicatissima	..	600	..	..	..
— seriata	3800	3800	3160	1125	20
Rhizosolenia alata	..	..	..	25	..
— Faerøensis	..	..	120	..	..
— fragilissima	..	..	..	50	..
— semispina	2600	2800	1160	1050	20
Skeletonema costatum	418000	235000	259200	131000	80
Thalassiosira decipiens	..	..	80	..	..
— gravida	14800	15600	17360	10500	160
— Nordenskiöldii	17200	11400	17280	4000	..
Thalassiothrix longissima	..	..	..	50	..
— nitzschioides	800	1200	200	425	..
Distephanus speculum	200	200	40	..	..
Ceratium bucephalum	..	..	40	..	..
— fusus	..	..	40	..	..
— macroceros	..	..	40	..	..
Dinophysis acuminata	..	200	..	..	..
Gymnodinium Lohmanni	200	200	..	..	..
— sp.	1600	400	200	..	..
Oxytoxum gracile	200	..	..	..	..
Peridinium achromaticum	200	..	..	..	..
— crassipes	..	..	40	..	..
— depressum	200	..	..	..	..
— geminum	..	400	..	..	..
— ovatum	..	..	40	25	..

Tabel XI. 1926. St. 48 (continued).

Depth	1	10	25	40	75
Temperature	4.66	4.62	4.65	4.91	6.32
Salinity	33.40	33.39	33.49	33.75	34.65
σ_t	26.49	26.48	26.56	26.72	27.25
Oxygen, cc pr. l.	7.61	7.70	7.46	6.82	6.42
— saturation %	106.0	107.1	106.3	95.8	94.3
Number of cc examined	5	5	25	40	50
Peridinium pellucidum	..	400	..	..	..
— Steinii	..	200	..	..	..
— sp.	..	..	80	75	..
Tintinnopsis ventricosa	..	..	..	25	..
Cyttarocylis denticulata	..	..	..	25	..
Laboea acuminata	400	..	..	..	..
— constricta	..	..	40	..	..
— crassula	200	..	..	..	..
— vestita	800	..	..	25	60
Lohmanniella oviformis	400	..	40	..	..
— spiralis	..	..	40	..	..
Mesodinium rubrum	..	200	80	..	..
Infusoria cetera	..	200	..	..	..
Nauplii	..	..	40	..	..

Tabel XII. 1926. St. 49. April 9th. 1.30 p.m. 32′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.04	6.12	6.10	6.13	7.43
Salinity	34.38	34.43	34.54	34.63	35.23
σ_t	27.09	27.11	27.20	27.26	27.56
Oxygen, cc pr. l.	7.06	6.97	6.89	6.80	6.48
— saturation %	102.3	101.4	100.2	99.3	97.5
Number of cc examined	10	10	50	10	50
Asterionella japonica	4800	300	360	3600	160
Chaetoceras atlanticum	..	..	60	..	..
— boreale	1200	200	480	..	..
— breve	..	..	..	700	140
— constrictum	12100	9600	1960	5500	1440
— compressum	4300	..	..	1600	..
— curvisetum	1800	300	40	200	160
— debile	158800	118800	49650	62300	21540
— decipiens	1100	100	..	..	200
— diadema	12100	3100	1220	7800	4180
— laciniosum	3900	..	660[1])	800	560
— scolopendra	1800	300	240	600	140
— sociale	..	400	..	..	..
— teres	..	..	140	700	140
Coscinodiscus centralis	200	..	..	..	20

[1]) with spores.

Tabel XII. 1926. St. 49 (continued).

Depth	1	10	25	40	75
Temperature	6.04	6.12	6.10	6.13	7.43
Salinity	34.38	34.43	34.54	34.63	35.23
σ_t	27.09	27.11	27.20	27.26	27.56
Oxygen, cc pr. l.	7.06	6.97	6.89	6.80	6.48
— saturation %	102.3	101.4	100.2	99.3	97.5
Number of cc examined	10	10	50	10	50
Coscinodiscus subbulliens	100	..	..	..	20
Coscinosira polychorda	..	..	60	200	320
Eucampia groenlandica	..	..	..	..	40
Lauderia glacialis	300	100	100	600	40
Leptocylindrus danicus	8200	3300	2700	3100	580
Navicula gelida var.	2000	2000	2200	600	440
Nitzschia Closterium	..	..	40	100	20
— delicatissima	..	..	..	..	80
— seriata	4200	2800	3220	3700	980
Rhizosolenia alata	200	..	20	..	20
— faerøensis	..	..	40	..	..
— fragilissima	300	..	..	..	60
— semispina	1100	400	520	1100	180
Skeletonema costatum	2000	..	160	..	500
Thalassiosira decipiens	300	400	20	800	60
— gravida	19100	18800	16300	12700	6600
— Nordenskiöldii	10300	7100	10040	4600	1780
Thalassiothrix nitzschioides	1500	200	80	500	60
Distephanus speculum	..	..	..	100	..
Ceratium fusus	100	..	..	..	..
Gymnodinium Lohmanni	100	100	..	..	..
— gracile	..	..	100	..	..
Oxytoxum diploconus	..	..	..	100	20
— gracile	..	..	40	..	80
Peridinium conicum	100	..	..	..	..
— depressum	..	100	..	..	..
— geminum	100	..	60	..	..
— Steinii	..	..	40	100	..
— sp.	100	300	200	..	20
Tintinnopsis ventricosa	..	..	20	100	60
Cyttarocylis denticulata	100	..	20	..	..
— norvegica	..	..	20	..	..
Laboea acuminata	..	..	40	..	20
— conica	600	400	..	..	..
— constricta	100	..	..	..	60
— crassula	..	..	..	..	20
— strobila	..	200	..	..	20
— vestita	1300	400	..	..	..
Lohmanniella oviformis	100	200	20	..	..
Mesodinium rubrum	500	1500	..	..	..
Woodania conicoides	..	100	..	..	20
Ptychocylis urnula	200	..	..	..	..
Nauplii	..	..	20	..	20

Tabel XIII. 1926. St. 50. April 9th. 6 p.m. 50′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.51	7.63	7.40	7.61	7.41
Salinity	34.33	34.34	35.16	35.23	35.25
σ_t	26.84	26.85	27.50	27.54	27.57
Oxygen, cc pr. l.	7.13	6.72	6.91	6.56	6.53
— saturation %	106.8	100.8	103.8	98.9	98.1
Number of cc examined	10	50	50	50	50
Eutreptia Lanowii	100	..	..	..	..
Asterionella japonica	1100	220	280	..	..
Cerataulina Bergonii	..	..	20	..	..
Chaetoceras boreale	600	120	..	..	..
— breve	900	..	240	..	..
— compressum	4400	20	20	..	..
— constrictum	9000	640	2180	..	..
— curvisetum	..	..	60	..	..
— debile	127500	6760	58500	..	..
— decipiens	1000	40	220	..	..
— diadema	3300	80	1380	..	..
— laciniosum	400	100	120	..	..
— scolopendra	6800	180	220	..	..
— sociale	1400	..	..	..	..
— teres	..	..	80	..	..
Corethron criophilum	..	..	20	..	..
Coscinodiscus subbulliens	..	40	80	..	..
Coscinosira polychorda	500	40	650	40	60
Lauderia glacialis	100	80	250	..	..
Leptocylindrus danicus	2600	120	1180	..	..
Navicula gelida var.	1200	20	360	..	..
Nitzschia delicatissima	400	..	..	..	..
— seriata	3700	520	2760	..	..
Rhizosolenia alata	100	..	..	..	..
— faeroeensis	100	..	..	..	..
— fragilissima	200	180	220	..	..
— semispina	1000	40	720	..	..
Skeletonema costatum	..	60	180	..	100
Thalassiosira bioculata	100	..	..	..	..
— gravida	11600	2080	12400	160	100
— Nordenskiöldii	16100	1460	8750	60	+220
Thalassiothrix longissima	100	..	..	..	..
Ceratium fusus	..	20	..	20	..
— intermedium	..	..	..	20	..
Gymnodinium Lohmanni	..	..	40	..	..
Peridinium geminum	100	..	..	..	..
— pyriforme	..	..	20	..	..
— sp.	200	20	100	20	..
Cyttarocylis denticulata	100	..	..	..	..
— norvegica	100	..	40	..	..
Laboea acuminata	..	..	20	..	..
— constricta	..	..	..	..	20
— strobila	100	..	..	..	..
— vestita	500	..	..	..	20
Lohmanniella oviformis	..	20	40	..	..
Mesodinium rubrum	600	40	..	..	..
Nauplii	..	..	20	..	..

Tabel XIV. 1926. St. 51. April 10th. 11 a. m. Julsund.

Depth	1	10	25	40	75
Temperature	4.66	4.52	4.40	4.41	5.76
Salinity	31.94	32.83	33.03	33.10	33.93
σ_t	25.31	26.04	26.20	26.25	26.74
Oxygen, cc pr. l.	8.14	8.22	7.87	7.71	6.30
— saturation %	112.3	114.2	108.8	106.8	90.4
Number of cc examined	5	5	5	5	25
Eutreptia Lanowii	..	..	200	..	..
Achnanthes taeniata	..	..	3200	..	560
Asterionella japonica	..	200	200	..	..
Chaetoceras boreale	..	..	..	400	200
— — f. varians	..	1000	..	200	..
— compressum	..	..	1600	..	..
— constrictum	..	1400	600	..	120
— curvisetum	..	1400	1000	..	..
— debile	611200	779600	949800	776000	18040
— decipiens	..	400	..	600	120
— diadema	..	600	400	1200	280
— furcellatum (spores)	..	1600	..	..	..
— laciniosum	..	5400	10000	7200	600
— scolopendra	..	..	800	..	..
— sociale (spores)	..	1200	3800	1600	320
— teres	..	..	200	..	..
Lauderia borealis	..	..	..	..	80
— glacialis	..	..	..	400	120
Leptocylindrus minimus	..	..	1200	..	..
Navicula gelida var.	..	400	600	1200	200
Nitzschia Closterium	..	..	200	200	40
— seriata	..	..	200	600	..
Rhizosolenia faeroeensis	..	1200	..	200	..
Skeletonema costatum	12600	59800	208600	288800	1760
Thalassiosira decipiens	..	..	..	..	80
— gravida	800	600	1200	600	240
— Nordenskiöldii	..	1400	4000	2800	..
Thalassiothrix nitzschioides	2000	..	5000	1400	80
Distephanus speculum	..	..	..	200	..
Ceratium fusus	..	..	200	..	..
Dinophysis norvegica	..	200	..	..	..
Gymnodinium Lohmanni	200	..	..	..	..
— sp.	..	..	200	200	..
Peridinium depressum	..	200	..	..	..
— sp.	400	800	400	..	120
Pouchetia sp.	..	200	..	..	..
Oxytoxum gracile	..	200	..	..	..
Laboea conica	200	200	..	..	..
— constricta	..	..	200	..	..
— emergens	..	..	..	200	..
— strobila	200	200	..	..	..
— vestita	..	..	200	..	..
Lohmanniella oviformis	..	200	400	200	40
Mesodinium rubrum	600	..	..	..	80
Ptychocylis urnula	..	..	..	200	..
Infusoria cetera	..	..	..	200	..

Tabel XV. 1926. St. 52. April 28th. 2.30 p. m. Julsund.

Depth	1	10	25	40	75
Temperature	8.01	5.52	5.00	4.93	5.76
Salinity	30.41	32.47	33.06	33.22	33.89
σ_t	23.70	25.64	26.16	26.31	26.72
Oxygen, cc pr. l	7.40	7.35	7.13	6.88	6.35
— saturation %	109.1	104.0	100.0	96.4	91.1
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	20	..	..	..	..
Chaetoceras atlanticum	..	..	40	..	80
— boreale	20	..	..	..	..
— convolutum	60	..	..	..	..
— debile	420	..	..	sp.100	360
Coscinodiscus concinnus	20	..	..	..	..
Leptocylindrus minimus	1780	..	..	..	..
Thalassiosira gravida	..	..	20	..	..
Ceratium furca	..	20	..	..	..
— lineatum	..	20	..	..	..
— longipes	40	20	..	..	..
— tripos	..	20	..	..	..
Dinophysis norvegica	..	20	..	..	..
Diplopsalis lenticula	..	..	20	20	..
Gymnodinium Lohmanni	200	..	80	60	140
Peridinium crassipes	..	..	..	20	..
— ovatum	..	40	20	..	..
— pallidum	..	20	..	..	..
— sp.	360	..	20	20	..
Phalacroma rotundatum	20	20	..	..	..
Torodinium robustum	20	20	..	..	..
Cyttarocylis denticulata	20	..	..	..	..
Laboea conica	60	20	..	..	..
— constricta	..	..	40	..	40
— crassula	..	..	..	20	..
— strobila	20	..	40	..	..
Lohmanniella oviformis	160	..	60	..	..
Mesodinium rubrum	940	240	80	40	20
Ptychocylis urnula	..	60	40	40	..
Tintinnus acuminatus	..	..	20	..	..
Infusoria indeterminata	60	60	20	60	..

Tabel XVI. 1926. St. 53. April 28th. 6 p. m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.21	5.92	5.31	5.06	5.92
Salinity	32.66	33.10	33.17	33.31	34.25
σ_t	25.61	26.08	26.21	26.35	26.99
Oxygen, cc pr. l.	7.12	7.13	7.04	6.84	6.31
— saturation %	104.7	102.2	99.5	96.2	91.2
Number of cc examined	50	50	50	50	50
Ceratium furca	..	20	..	..	..
— longipes	20	60	20	..	..
— tripos	40	40	..	..	..
Peridinium depressum	20	..	..	40	..
Phalacroma rotundatum	..	..	20	20	..
Laboea conica	100	..	..	..	..
— constricta	..	..	..	20	..
— vestita	100	..	..	..	..
Lohmanniella oviformis	40	..	20	40	..
Mesodinium rubrum	260	40	20	..	..
Nauplii	..	40	..	..	..

Tabel XVII. 1926. St. 54. April 28th. 9 p. m. 15.5′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.39	5.42	4.95	5.01	6.01
Salinity	32.84	33.03	33.13	33.42	34.33
σ_t	25.82	26.09	26.22	26.45	27.04
Oxygen, cc pr. l.	7.11	7.10	6.84	6.86	6.33
— saturation %	102.6	100.6	95.9	96.5	91.6
Number of cc examined	50	50	50	50	50
Ceratium bucephalum	..	20	..	..	..
— fusus	..	20	..	..	..
— longipes	20	20	..	..	..
— tripos	80	60	..	..	..
Peridinium crassipes	..	20	..	20	..
— depressum	..	..	..	20	..
— ovatum	..	..	20	..	..
— pallidum	..	..	20	..	..
Phalacroma rotundatum	20	..	..	20	..
Laboea constricta	..	..	..	20	..
Lohmanniella oviformis	..	..	20	..	..
Mesodinium rubrum	120	20	40	20	..
Tintinnus acuminatus	..	..	..	20	..
Infusoria indeterminata	..	..	..	20	..
Nauplii	..	20	40	..	..
Oithona similis	..	..	20	..	..
Larvæ of Ophiurida	..	20	..	..	..

Tabel VIII. 1926. St. 55. April 29th. 6 a. m. 32′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.32	5.17	5.50	6.01	7.11
Salinity	32.61	33.28	33.82	34.29	34.96
σ_t	25.52	26.32	26.41	27.01	27.38
Oxygen, cc pr. l.	7.02	6.81	6.54	6.52	6.23
— saturation %	103.4	96.1	95.4	94.3	93.2
Number of cc examined	50	50	50	50	50
Thalassiosira Nordenskiöldii	..	100	20	..	..
Ceratium furca	..	..	..	20	..
— longipes	40	..	..	20	..
— tripos	20	60	20	..	..
Diplopelta bomba	..	..	..	20	..
Peridinium ovatum	..	..	..	..	20
— sp.	..	..	20	..	..
Phalacroma rotundatum	60	..	..	..	..
Cyttarocylis denticulata	..	..	..	20	20
Laboea constricta	..	..	..	20	..
Mesodinium rubrum	..	20	20	..	..
Oithona	..	20	..	..	..
Nauplii	..	..	40	20	..

Tabel XIX. 1926. St. 56. April 29th. 10 a. m. 44′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.01	8.27	8.35	8.61	8.66
Salinity	34.13	34.87	35.23	35.35	35.37
σ_t	26.61	27.15	27.41	27.48	27.49
Oxygen, cc pr. l.	7.31	7.13	6.46	6.67	6.55
— saturation %	110.4	109.0	99.1	103.0	101.4
Number of cc examined	50	50	50	..	..
Coscinodiscus subbulliens	..	..	20	..	..
Coscinosira polychorda	..	..	20	..	..
Thalassiosira gravida	..	20	..	..	..
Peridinium depressum	20	..	..	..	..
Cyttarocylis denticulata	..	..	20	..	..
Laboea conica	20	..	..	..	..
— vestita	40	..	..	..	..
Lohmanniella oviformis	140	..	..	..	..

Tabel XX. 1926. St. 57. April 29th. 1 p. m. 50′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.96	8.52	8.50	8.66	8.67
Salinity	34.69	35.03	35.26	35.37	35.52
σ_t	26.91	27.24	27.45	27.49	27.60
Oxygen, cc pr. l.	7.21	7.02	6.60	6.23	6.24
— saturation %	111.8	107.8	101.5	96.5	96.9
Number of cc examined	50	50	50	50	50
Actinocyclus Ehrenbergii	..	..	..	20	..
Chaetoceras atlanticum	..	..	..	80	..
— boreale	20	80	..	..	..
— compressum	..	20	..	..	..
— debile (spores)	..	40	..	..	..
— decipiens	..	420	..	..	..
— densum	..	40	..	..	..
— constrictum	..	60	..	..	..
— diadema	..	..	..	..	80
— laciniosum	..	20	..	..	..
Cerataulina Bergonii	..	20	..	..	..
Coscinodiscus excentricus	..	..	20	..	..
— subbulliens	..	20	40	..	..
Coscinosira polychorda	..	80	120	20	..
Leptocylindrus danicus	..	1920	40	..	..
Navicula gelida var.	..	20	..	..	..
Nitzschia Closterium	..	20	..	..	..
Rhizosolenia Faeroeensis	..	160	..	..	..
— fragilissima	..	480	20	..	..
Thalassiosira gravida	20	..	..	20	20
— subtilis	..	40	40	20	40
Thalassiothrix nitzschioides	..	40	..	..	60
Distephanus speculum	..	..	..	20	..
Pterosperma Vanhöffeni	..	..	..	..	20
Ceratium fusus	..	20	..	40	..
— longipes	20	..	..	..	..
— tripos	..	20	20	..	..
Exuviaella baltica	..	..	20	20	..
Dinophysis acuta	..	20	..	..	..
Peridinium ovatum	..	..	..	20	..
— pallidum	..	40	..	..	..
— sp.	..	40	40	20	..
Cyttarocylis denticulata	..	20	20	..	20
— norvegica	40	..	..	..	..
Laboea conica	1040	..	..	..	..
— constricta	..	..	20	40	..
— emergens	..	..	..	..	20
— strobila	80	..	..	..	..
— vestita	200	..	100	20	..
Lohmanniella oviformis	20	..	80	..	..
Mesodinium rubrum	140	..	20	20	..
Woodania conicoides	260	..	..	..	..
Infusoria indeterminata	..	..	20	..	..
Nauplii	..	..	..	20	..

Tabel XXI. 1926. St. 60. May 12th. 7.30 a. m. Julsund.

Depth	1	10	25	40	75
Temperature	6.36	6.27	5.30	5.59	6.38
Salinity	32.27	32.72	33.44	33.78	34.45
σ_t	25.37	25.74	26.42	26.67	27.09
Oxygen, cc pr. l.	7.39	7.39	6.82	6.48	6.28
— saturation %	106.3	106.4	96.6	92.6	92.6
Number of cc examined	50	50	50	50	50
Cerataulina Bergonii	..	..	..	20	..
Chaetoceras atlanticum	..	..	60	..	..
— cinctum	..	80	..	180	..
— debile	100	100	..	..	..
Eucampia groenlandica	..	60	..	..	..
Leptocylindrus minimus	40	340	100	360	..
Lauderia glacialis	..	..	20	..	..
Navicula directa	..	20	..	..	..
Thalassiothrix nitzschioides	..	..	..	..	60
Ceratium furca	20	20	..	..	..
— fusus	..	..	..	20	..
— longipes	20	20	..	20	..
Diplopsalis lenticula	..	..	..	20	..
Gymnodinium Lohmanni	20	20	..	..	..
Peridinium achromaticum	..	20	..	..	..
— depressum	..	..	20	..	..
— ovatum	..	..	20	20	..
— sp.	..	20	20	20	..
Cyttarocylis denticulata	..	20	..	..	..
Laboea conica	20	80	..	..	..
— crassula	..	40	..	..	..
— vestita	20	40	..	..	..
Lohmanniella oviformis	100	140	..	..	..
Mesodinium rubrum	60	240	..	40	..
Infusoria indeterminata	40	40	..	..	..
Nauplii	..	..	40	..	20
Fritillaria borealis	20	..	..	..	..

Tabel XXII. 1926. St. 61. May 12th. 10.30 p. m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.69	6.19	5.67	5.74	6.51
Salinity	32.95	33.08	33.91	34.05	34.63
σ_t	25.57	26.04	26.76	26.86	27.21
Oxygen, cc pr. l	7.04	7.14	6.54	6.33	6.27
— saturation %	102.4	103.0	93.6	90.8	92.2
Number of cc examined	50	50	50	50	50
Actinocyclus Ehrenbergii	..	..	..	..	20
Chaetoceras cinctum	100	..	..	..	..
— debile	60	..	..	..	..
Skeletonema costatum	60	..	..	..	..
Thalassiothrix nitzschioides	..	20	20	..	..
Ceratium longipes	40	20	..	..	..
Peridinium ovatum	..	..	..	40	..
— sp.	..	..	20	..	..
Pterosperma dictyon	20	..	..	..	..
Cyttarocylis denticulata	40	..	..	..	..
Laboea conica	140	..	..	..	..
— emergens	..	..	40	20	..
— strobila	120	..	..	..	..
Lohmanniella oviformis	20	..	..	20	..
Mesodinium rubrum	40	..	40	..	..
Woodania conicoides	20	..	..	..	..
Infusoria indeterminata	20	..	..	..	..

Tabel XXIII. 1926. St. 62. May 12th. 1.50 p. m. 17.5′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.27	5.47	5.40	5.72	6.93
Salinity	33.08	33.33	33.64	34.00	34.76
σ_t	25.89	26.31	26.57	26.82	27.26
Oxygen, cc pr. l	7.38	7.12	6.57	6.43	6.16
— saturation %	109.0	101.2	93.5	92.3	91.4
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	100	..	..	..	..
Chaetoceras cinctum	1080	..	..	..	..
— debile	5140	..	..	..	..
Leptocylindrus minimus	320	..	..	..	..
Navicula gelida var.	..	..	..	..	20
Skeletonema costatum	160	..	..	..	..
Thalassiosira decipiens	..	..	40	..	20
Ceratium tripos	..	..	20	..	..
Gymnodinium Lohmanni	..	..	..	..	20
Peridinium depressum	..	..	..	..	20
— ovatum	..	20	..	..	20
— sp.	20	..	..	..	..
Phalacroma rotundatum	..	..	..	40	..
Torodinium robustum	..	..	20	..	..
Cyttarocylis denticulata	..	..	..	..	20
Laboea conica	60	..	..	..	..
— strobila	40	..	..	..	..
— vestita	60	..	..	..	..
Lohmanniella oviformis	80	..	..	..	..
Mesodinium rubrum	..	20	20	20	..
Woodania conicoides	..	20	..	..	..
Infusoria indeterminata	..	20	..	..	..
Nauplii Microsetellae	..	..	..	40	..
Oithona similis	..	20	..	..	..

Tabel XXIV. 1926. St. 63. May 12th. 5 p. m. 31.5′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.27	6.44	5.70	5.87	7.41
Salinity	32.81	32.88	33.22	34.29	34.92
σ_t	25.67	25.84	26.22	27.03	27.31
Oxygen, cc pr. l	7.28	7.55	7.07	6.33	6.29
— saturation %	107.4	111.0	100.7	91.4	94.5
Number of cc examined	50	50	50	50	50
Ceratium intermedium	..	..	20	..	..
— longipes	..	..	20	..	..
— tripos	..	..	20	..	..
Peridinium depressum	20	..	..	60	..
— sp.	..	..	..	20	20
Laboea conica	..	..	..	..	20
— constricta	..	..	20	..	20
— emergens	..	20	60	..	..
— strobila	40	..	..	..	..
— vestita	20	..	..	..	..
Lohmanniella oviformis	..	..	100	..	20
Mesodinium rubrum	220	20	..	60	..
Woodania conicoides	120	20	..	..	..
Infusoria indeterminata	..	..	..	20	..
Tintinnus acuminatus	..	..	..	..	20
Larvae of Annelida	..	..	20	..	..

Tabel XXV. 1926. St. 64. May 12th. 8 p. m. 45′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	7.34	6.93	8.01	8.32	8.63
Salinity	33.01	33.33	35.01	35.10	35.25
σ_t	25.81	26.13	27.31	27.33	27.39
Oxygen, cc pr. l	7.19	7.24	6.29	6.30	6.35
— saturation %	106.4	106.3	95.7	96.5	98.1
Number of cc examined	50	50	50	50	50
Coscinodiscus excentricus	..	..	..	20	..
Leptocylindrus danicus	40	160	..	..	40
Thalassiosira subtilis	..	60	..	..	..
Ceratium arcticum	20	20	..	..	..
— longipes	140	140	..	..	..
— macroceros	..	20	..	..	..
— tripos	20	80	..	20	..
Gymnodinium sp.	60	..	..	..	..
Minuscula bipes	40	..	..	..	..
Peridinium sp.	20	..	..	..	..
Phalacroma rotundatum	20	..	..	..	..
Cyttarocylis denticulata	..	20	..	..	..
— norvegica	220	20	..	..	..
Laboea conica	100	..	..	..	..
— crassula	120	..	..	..	..
— strobila	60	..	..	..	..
— vestita	380	..	..	..	..
Lohmanniella oviformis	820	100	..	..	..
Mesodinium rubrum	140	..	..	..	..
Woodania conicoides	1200	..	..	..	..
Laboea sp.	..	..	20	..	..
Nauplii	..	40	..	..	..

Tabel XXVI. 1926. St. 66. June 1st. Julsund.

Depth	1	10	25	40	75
Temperature	8.93	6.88	6.15	6.11	6.83
Salinity	31.92	33.17	33.62	34.02	34.85
σ_t	24.74	26.01	26.47	26.79	27.36
Oxygen, cc pr. l	8.14	7.88	7.10	6.61	6.11
— saturation %	123.3	115.3	102.8	95.9	90.4
Number of cc examined	50 (5)	5	10	50	50
Actinocyclus Ehrenbergii	..	..	..	..	20
Chaetoceras atlanticum	..	160	450	1020	..
— boreale	..	80	..	160	..
— cinctum	..	560	13000	..	..
— compressum	..	540	2750	320	..
— constrictum	3200	1840	4650	600	..
— curvisetum	600	640	650	80	..
— debile	367400	910200	1317500	221200	..
— decipiens	2600	3120	6400	4780	..
— diadema	2400	1920	2700	520	..
— laciniosum	19200	3400	5350	1780	..
— Schüttii	..	..	750	..	..
— teres	..	560	850	440	..
Coscinodiscus concinnus	..	120	50	20	..
Coscinosira polychorda	..	810	900	40	..
Eucampia groenlandica	..	2000	500	..	..
Leptocylindrus danicus	3200	1840	4050	1440	..
— minimus	22200	12600	8300	2940	..
Lauderia glacialis	..	40	..	40	..
Navicula gelida var.	..	..	..	60	..
Nitzschia Closterium	1400	2200	1500	520	..
— delicatissima	43400	28000	18300	2920	..
— seriata	1200	2040	3450	2600	..
Pleurosigma sp.	..	..	100	80	..
Rhizosolenia alata	..	120	100	160	..
— faeroeensis	..	80	400	80	..
— fragilissima	5200	5600	8200	1420	..
— semispina	..	..	..	80	..
— Shrubsolei	..	..	..	20	..
Skeletonema costatum	97600	111000	77500	72640	..
Thalassiosira bioculata	200	480	350	300	..
— gravida	..	1040	800	940	..
Thalassiothrix nitzschioides	4200	480	100	1200	..
Distephanus speculum	..	..	..	20	..
Ceratium lineatum	..	40	..	..	..
— longipes	90	40	50	..	..
— tripos	..	40	..	20	..
Dinophysis acuminata	40	80	..	20	..
— norvegica	..	40	150	120	..
Exuviaella sp.	..	40	..	40	..
Diplopsalis lenticula	..	40	50	20	..
Minuscula bipes	..	80	..	40	..
Oxytoxum gracile	..	..	..	20	..
Peridinium sp.	..	240	50	40	..
Phalacroma rotundatum	..	40	..	..	20
Torodinium robustum	..	..	..	20	..
Peridinium pellucidum	..	120	..	..	..
— depressum	..	20	50		

Tabel XXVI. 1926. St. 66 (continued).

Depth	1	10	25	40	75
Temperature	8.93	6.88	6.15	6.11	6.83
Salinity	31.92	33.17	33.62	34.02	34.85
σ_t	24.74	26.01	26.47	26.79	27.36
Oxygen, cc pr. l.	8.14	7.88	7.10	6.61	6.11
— saturation %	123.3	115.3	102.8	95.9	90.4
Number of cc examined	50 (5)	5	10	50	50
Cyttarocylis denticulata	20	160	..	60	..
— norvegica	40	40	..	..	..
Laboea conica	80	40	..	20	..
— acuminata	..	120	..	..	..
— constricta	40	..	..	20	..
— emergens	..	..	..	20	..
— vestita	80	..	..	..	..
Lohmanniella oviformis	..	40	..	20	..
— spiralis	20	..	..	..	..
Mesodinium rubrum	400	120	100	..	..
Tintinnus acuminatus	..	40	150	..	..
Infusoria indeterminata	20	..	..	20	..
Nauplii	..	80	150	20	..
Fritillaria borealis	240	160	100	..	..
Synchaeta sp.	..	80	..	..	..

Tabel XXVII. 1926. St. 67. June 2nd. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.13	7.09	6.40	6.19	6.43
Salinity	33.10	33.37	33.87	34.02	34.55
σ_t	25.78	26.14	26.64	26.78	27.16
Oxygen, cc pr. l	6.30	6.97	6.74	6.55	6.01
— saturation %	94.9	102.8	98.3	95.1	88.1
Number of cc examined	50	25	50	50	50
Chaetoceras atlanticum	..	..	120	100	..
— cinctum	..	..	2040	160	..
— constrictum	..	..	240	..	..
— curvisetum	..	..	100	..	..
— debile	840	240	136300	1800	420
— decipiens	..	..	600	280	..
— diadema	..	..	140	..	..
— laciniosum	..	..	840	120	..
— teres	..	..	100	..	..
Coscinosira polychorda	..	..	200	..	..
Eucampia groenlandica	..	..	200	..	..
Leptocylindrus danicus	..	..	400	..	..
— minimus	..	..	4520	320	..
Navicula directa	..	..	20	..	..
Nitzschia Closterium	..	40	360	..	..
— delicatissima	..	..	4500	..	40
— seriata	..	..	1660	140	..
Pleurosigma sp.	..	..	20	..	..
Rhizosolenia fragilissima	..	80	2780	240	..
Skeletonema costatum	..	..	37100	2880	180
Thalassiosira gravida	..	..	240	80	..
Thalassiothrix nitzschioides	..	..	100	180	..
Ceratium furca	20	..	..	..	..
— longipes	40	80	..	..	..
— tripos	..	80	..	..	..
Exuviaella sp.	..	..	..	..	20
Peridinium sp.	60	..	..	..	..
Laboea conica	360	..	..	..	..
— constricta	..	..	..	20	..
— emergens	..	..	..	20	..
— strobila	80	..	..	..	..
— vestita	..	40	..	..	..
Lohmanniella oviformis	..	..	40	..	..

Tabel XXVIII. 1926. St. 68. June 2nd. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.33	7.75	6.23	6.19	7.07
Salinity	33.01	33.17	33.53	34.00	34.34
σ_t	25.68	25.89	26.38	26.76	26.90
Oxygen, cc pr. l.	6.98	7.07	6.91	6.17	6.16
— saturation %	105.4	105.6	99.9	89.4	91.4
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	20	..	..	..	..
Actinocyclus Ehrenbergii	..	..	..	20	20
Chaetoceras debile	120	1340	..	..	..
Nitzschia seriata	..	..	60	..	..
Thalassiosira gravida	..	20	..	..	..
Ceratium intermedium	..	20	..	..	..
— longipes	60	60	20	..	..
— tripos	20	20	20	..	..
Gymnodinium Lohmanni	20	..	..	..	..
Peridinium ovatum	..	20	20	..	..
Cyttarocylis norvegica	260	..	..	..	..
Laboea conica	60	..	..	..	..
— constricta	..	..	20	..	..
— crassula	..	100	..	..	..
— emergens	..	140	40	..	..
— strobila	40	..	..	..	..
— vestita	40	280	100	20	..
Lohmanniella oviformis	20	80	..	..	..
Nauplii	..	40	20	20	..

Tabel XXIX. 1926. St. 69. June 2nd. 32′ NW. Björnsund.

Depth	1	10	40	75
Temperature	8.93	8.44	7.95	8.28
Salinity	32.99	33.08	35.12	35.25
σ_t	25.58	25.72	27.40	27.44
Oxygen, cc pr. l.	6.76	6.86	6.25	6.33
— saturation %	103.4	104.0	95.4	97.1
Number of cc examined	50	50	50	50
Actinocyclus Ehrenbergii	..	..	20	..
Chaetoceras cinctum	..	..	..	sp. 360
— debile	..	100	..	sp. 300
Leptocylindrus danicus	60	40	..	..
Navicula gelida var.	..	..	20	..
Nitzschia delicatissima	20	60	60	..
— seriata	60	40	860	60
Rhizosolenia alata	..	..	20	20
— faeroeensis	..	..	20	..
Thalassiosira gravida	..	20	40	..
— subtilis	140	1780	80	..
Ceratium furca	20	..	..	..
— fusus	20	20	..	..
— lineatum	..	20	..	..
— longipes	120	280	..	..
— tripos	40	40	..	20
Dinophysis acuminata	..	80	..	..
— norvegica	..	40	..	..
Exuviaella sp.	..	160	60	40
Peridinium crassipes	..	20	..	..
— ovatum	..	20	..	..
— sp.	20	120	..	..
Phalacroma rotundatum	..	120	..	..
Cyttarocylis denticulata	40	60	..	..
— norvegica	20	20	20	60
Laboea conica	..	20	..	..
— constricta	..	20	20	..
— crassula	..	20	..	..
— vestita	..	..	20	..
Lohmanniella oviformis	..	40	..	60
Ptychocylis urnula	..	..	20	..
Nauplii	..	40	..	..
Oithona	..	20	..	..
Fritillaria borealis	..	20	..	..

Tabel XXX. 1926. St. 70. June 2nd. 46′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.18	8.10	5.99	6.26	8.46
Salinity	32.86	32.94	34.25	34.45	35.25
σ_t	25.58	25.65	26.98	27.11	27.41
Oxygen, cc pr. l	6.91	6.93	6.57	6.30	..
— saturation %	104.0	104.2	95.1	92.0	..
Number of cc examined	50	50	50	50	50
Asteromphalus heptactis	..	..	..	..	20
Chaetoceras convolutum	..	..	..	..	40
— curvisetum	..	80	..	..	..
— teres	..	..	20	..	..
Coscinodiscus concinnus	20	..	..	..	..
Coscinosira polychorda	..	..	..	20	..
Skeletonema costatum	..	..	..	..	40
Thalassiosira gravida	..	..	..	20	..
Ceratium bucephalum	..	20	..	..	..
— furca	..	40	..	..	..
— longipes	220	200	20	..	..
— macroceros	..	..	20	..	..
— tripos	20	80	20	..	..
Exuviaella sp.	..	20	..	20	..
Minuscula bipes	..	20	..	..	..
Peridinium depressum	..	..	20	20	..
— ovatum	20	..	..	..	..
— pallidum	..	..	20	..	..
Phalacroma rotundatum	..	20	..	..	..
Torodinium robustum	..	..	20	..	..
Cyttarocylis denticulata	..	20	..	..	..
Laboea emergens	..	..	40	..	..
— strobila	..	..	40	20	..
— vestita	..	20	360	..	..
Lohmanniella oviformis	20	..	..	20	..
Mesodinium rubrum	..	..	20	..	..
Nauplii	40	20	..	..	..

Tabel XXXI. 1926. St. 78. June 24th. 3 p. m. Julsund.

Depth	1	10	25	40	75
Temperature	8.31	7.62	6.77	6.73	6.90
Salinity	33.24	33.40	34.07	34.22	34.56
σ_t	25.87	26.09	26.74	26.86	27.10
Oxygen, cc pr. l.	7.49	7.60	6.26	5.98	5.83
— saturation %	113.3	113.4	92.1	87.9	88.5
Number of cc examined	25	25	25	50	50
Eutreptia Lanowii	40	80	..	..	..
Chaetoceras atlanticum	120	560	760	280	..
— boreale	160	320	40	..	..
— compressum	62800	66920	3560	1740	..
— constrictum	..	..	..	40	..
— convolutum	80	..	..	..	..
— curvisetum	4040	2480	440	..	..
— debile	49640	46760	22640	5900	280
— decipiens	..	120	80	180	..
— laciniosum	1640	880	..	220	..
— pseudocrinitum	..	440	..	..	..
— Schüttii	1120	3640	480	..	..
Coscinodiscus concinnus	..	..	..	40	..
Coscinosira polychorda	..	360	360	220	20
Guinardia flaccida	..	..	80	..	..
Lauderia borealis	440	320	960	..	..
Leptocylindrus danicus	1400	1520	1400	260	..
— minimus	360	..	..	..	..
Nitzschia delicatissima	58560	46280	8120	1860	160
— seriata	1120	2200	2760	540	20
Rhizosolenia alata	40	320	160	180	..
— faeroeensis	..	600	560	140	20
— Shrubsolei	..	40	120	80	..
Skeletonema costatum	..	280	160	360	..
Thalassiosira bioculata	40	..	80	140	..
— decipiens	..	..	120	..	20
— gravida	40	320	320	80	..
— Nordenskiöldii	40	360	..	..	..
Thalassiothrix nitzschioides	440	..	360	40	..
Ceratium fusus	40	40	..	..	..
— longipes	240	160	..	..	..
Dinophysis acuminata	280	120	..	..	..
— norvegica	80	280	..	..	..
Peridinium depressum	..	40	..	..	..
Protoceratium reticulatum	..	40	..	..	..
Phalacroma rotundatum	..	40	..	..	..
Gymnodinium Lohmanni	..	..	80	20	20
Laboea strobila	..	40	..	..	..
— crassula	40	..	..	..	..
Cyttarocylis denticulata	120	..	..	20	..
— norvegica	40	..	40	..	..
Lohmanniella oviformis	280	200	..	..	..
Mesodinium rubrum	200	400	..	..	..
Infusoria cetera	..	..	80	20	..

Tabel XXXII. 1926. St. 80. June 24th. 11.45 p. m. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	10.13	10.13	7.31	5.93	6.86
Salinity	32.61	32.70	33.49	34.11	34.63
σ_τ	25.09	25.15	26.21	26.88	27.17
Oxygen, cc pr. l.	6.64	6.61	7.24	6.38	6.14
— saturation %	104.0	103.6	107.3	91.4	91.0
Number of cc examined	50	50	50	50	50
Eutreptia Lanowii	..	20	20	20	..
Chaetoceras atlanticum	..	..	60	..	..
— compressum	3660	500	8840	..	..
— constrictum	40	..	..	..	..
— convolutum	..	..	80	..	.. *
— curvisetum	1140	..	920	..	..
— debile	23540	6860	72180	..	..
— decipiens	..	80	140	..	..
— diadema	80	..	..	..	..
— laciniosum	280	..	1120	..	..
— Schüttii	160	..	780	..	..
Leptocylindrus danicus	960	420	2120	100	..
— minimus	..	..	80	..	..
Nitzschia delicatissima	28120	9100	8460	..	..
— seriata	660	220	600	60	..
Rhizosolenia alata	..	..	40	..	..
— faeroeensis	..	..	420	..	..
— fragilissima	..	..	100	..	..
— Shrubsolei	20	..	80	..	..
— Stolterfothii	..	..	120	..	..
Skeletonema costatum	180	..	..	..	..
Thalassiosira gravida	100	100	200	..	20
Thalassiothrix nitzschioides	400	60	..	..	..
Ceratium fusus	..	..	20	..	..
— intermedium	40	..	..	..	..
— longipes	60	80	60	..	..
— macroceros	..	20	..	..	..
— tripos	140	100	80	..	..
Dinophysis norvegica	20	..	20	..	..
Diplopsalis lenticula	..	..	20	..	..
Gymnodinium Lohmanni	..	..	..	..	20
Peridinium ovatum	..	..	20	20	..
— conicum	20	..	..	..	..
— sp.	..	120	..	..	..
Laboea conica	20	20	..	..	..
— crassula	40	..	..	..	..
— strobila	40	..	..	..	..
Lohmanniella oviformis	60	20	..	40	..
— spiralis	140	..	..	..	..
Cyttarocylis norvegica	140	60	60	20	..
— denticulata	..	..	60	60	..
Tintinnus acuminatus	20	..	..	..	..

Tabel XXXIII. 1926. St. 82. June 25th. 6.30 p. m. 45′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	10.93	10.99	9.51	9.40	9.10
Salinity	32.43	32.83	35.17	35.28	35.25
σ_t	24.81	25.11	27.20	27.28	27.31
Oxygen, cc pr. l	6.49	6.44	6.45	6.23	6.13
— saturation %	103.1	102.9	101.4	97.8	96.4
Number of cc examined	50	50	50	50	50
Asteromphalus heptactis	..	..	..	40	..
Nitzschia seriata	..	..	..	..	20
Thalassiosira bioculata	..	..	..	..	20
— decipiens	20	..	..	..	80
Amphidinium sp.	..	..	20	..	..
Ceratium intermedium	..	..	20	..	..
— longipes	40	100	..	..	..
— macroceros	..	20	..	..	..
— tripos	60	80	..	..	..
Dinophysis acuminata	..	..	..	20	..
— norvegica	..	..	20	..	..
Phalacroma sp.	..	..	..	..	20
Peridinium sp.	..	..	40	..	20
Cyttarocylis norvegica	..	20	100	..	..
Laboea crassula	..	80	20	..	..
— emergens	20	..	..	..	40
— strobila	20	..	..	20	..
— vestita	..	..	420	..	..
Lohmanniella oviformis	..	60	300	40	..
— spiralis	..	..	..	..	20
Strombidium sp.	..	..	..	20	20
Tintinnus acuminatus	..	..	..	..	20
Infusoria	..	..	20	..	..
Oithona	..	20	..	..	..
Nauplii	60	20	..	20	..

Tabel XXXIV. 1927. St. 101. March 1st. 8 a. m. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	2.99	4.97	5.57	5.67	5.93
Salinity	32.86	33.26	33.62	..	33.86
σ_t	26.20	26.32	26.54	..	26.68
Oxygen, cc pr. l.	7.08	7.10	6.85	6.86	6.75
— saturation %	94.3	99.9	97.6	..	97.3
Number of cc examined	50	50	50	50	50
Actinoptychus undulatus	..	..	..	20	..
Chaetoceras sociale	60	..	..	..	..
Coscinodiscus concinnus	20	..	..	..	..
— radiatus	20	..	20	20	..
Coscinosira polychorda	40	20	..	..	..
Dactyliosolen tenuis	..	..	..	40	..
Lauderia borealis	320	..	..	..	..
— glacialis	..	220	..	..	..
Navicula gelida var.	..	..	20	..	..
Nitzschia Closterium	40	..	20	..	..
— delicatissima	980	440	240	20	..
— seriata	20	..	..	..	..
Paralia sulcata	..	..	..	..	280
Skeletonema costatum	7280	3060	2740	560	..
Thalassiosira decipiens	100	20	..	..	..
— gravida	20	240	..	..	..
Thalassiothrix nitzschioides	..	100	..	..	..
Distephanus speculum	..	..	20	20	..
Ceratium furca	20	40	20	..	..
— fusus	..	20	..	..	..
— lineatum	20	20	..	..	..
— longipes	20	20	..	..	..
— tripos	..	20	..	..	20
Peridinium achromaticum	20	..	..	..	..
— crassipes	..	..	20	..	..
— sp.	..	..	..	..	20
Gymnodinium sp.	80	60	20	..	..
Gonyaulax spinifera	..	20	..	..	..
Laboea constricta	..	..	..	20	..
Lohmanniella oviformis	..	..	..	20	40
— spiralis	..	20	..	..	..
Mesodinium rubrum	60	60	20	..	..
Nauplii	..	..	20	..	20

Tabel XXXV. 1927. St. 102. March 1st. 11 a. m. 17′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	5.26	5.61	5.96	6.30	6.41
Salinity	33.58	33.82	34.04	34.11	34.18
σ_7	26.55	26.70	26.81	26.83	26.88
Oxygen, cc pr. l	7.05	6.87	6.76	..	6.61
— saturation %	99.9	98.3	97.5	..	96.5
Number of cc examined	50	50	50	50	50
Halosphaera viridis	..	..	40	..	..
Actinocyclus Ehrenbergii	..	..	..	20	..
Chaetoceras debile	80	..	..	..	..
— furcellatum	120	..	..	..	..
— laciniosum	100	..	..	..	..
— simile	60	60	..	..	..
— sociale	300	..	..	..	..
Coscinodiscus radiatus	..	..	40	..	..
Coscinosira polychorda	420	200	..	..	..
Lauderia glacialis	140	..	..	..	..
Navicula gelida var.	..	20	..	..	..
Nitzschia Closterium	80	..	..	20	..
— delicatissima	8600	680	260	20	40
Skeletonema costatum	109180	6600	1500	..	..
Thalassiosira decipiens	260	20	100	..	20
— gravida	1060	140	..	..	..
Thalassiothrix nitzschioides	500	400	140	..	..
Distephanus speculum	60	20	..	..	..
Ceratium furca	40	20	..	..	..
— bucephalum	..	20	..	..	..
— tripos	20	40	..	..	..
— lineatum	..	80	..	..	..
— fusus	..	..	20	..	..
Peridinium sp.	..	..	20	..	..
Laboea vestita	20	..	..	..	..
Lohmanniella oviformis	60	60	20	..	40
— spiralis	20	20	..	..	..
Mesodinium rubrum	120	..	..	..	..
Cyttarocylis denticulata	..	..	..	..	40
Infusoria cetera	..	..	..	..	20
Oncæa sp.	..	..	..	..	20

Tabel XXXVI. 1927. St. 103. March 1st. 1.45 p. m. 32′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	5.59	5.92	6.14	6.66	7.53
Salinity	33.78	33.95	34.07	34.31	34.97
σ_t	26.67	26.75	26.82	26.94	27.35
Oxygen, cc pr. l.	6.63	6.83	6.66	6.47	6.41
— saturation %	94.7	98.4	96.7	95.2	96.4
Number of cc examined	50	50	50	50	50
Actinocyclus Ehrenbergii	20	..	20	..	..
Coscinodiscus radiatus	..	..	20	..	20
Coscinosira polychorda	160	..	..	..	..
Leptocylindrus danicus	..	40	..	..	..
Paralia sulcata	..	80	..	..	..
Rhizosolenia semispina	..	40	..	..	..
Navicula gelida var.	..	..	..	20	..
Nitzschia Closterium	..	..	..	20	..
— delicatissima	1040	..	..	..	..
Skeletonema costatum	14960	260	800	120	380
Thalassiosira decipiens	80	..	..	..	..
— gravida	340	..	..	..	..
Thalassiothrix nitzschioides	..	220	..	40	..
Ceratium bucephalum	20	..	..	..	..
— furca	40	..	..	..	..
— fusus	20	..	..	..	20
— tripos	20	..	..	..	..
Laboea acuminata	20	..	..	..	..
— vestita	..	40	..	..	..
Lohmanniella oviformis	..	..	20	..	..
Infusoria cetera	..	20	..	..	..
Oithona	..	..	..	20	..

Tabel XXXVII. 1927. St. 104. March 1st. 5.15 p. m. 48′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.99	6.99	6.96	6.93	6.92
Salinity	35.10	35.12	35.15	35.14	35.10
σ_t	27.52	27.53	27.56	27.56	27.55
Oxygen, cc pr. l.	6.66	6.57	6.65	6.40	6.59
— saturation %	99.3	97.9	98.9	95.2	97.9
Number of cc examined	50	50	50	50	50
Asterionella japonica	..	..	..	20	..
Coscinodiscus excentricus	..	..	20	..	..
Coscinosira polychorda	..	..	20	..	..
Skeletonema costatum	120	..	..	..	..
Thalassiosira decipiens	..	60	..	..	..
— gravida	..	..	40	..	..
Ceratium fusus	20	..	..	..	..
Minuscula sp.	..	..	20	40	..
Laboea vestita	..	..	20	..	..
Mesodinium rubrum	40	60	60	..	..
Cyttarocylis denticulata	..	20	..	..	..
Infusoria cetera	..	20	..	..	..

Tabel XXXVIII. 1927. St. 105. March 2nd. 5.30 a. m. Julsund.

Depth	1	10	25	40	75
Temperature	3.90	4.49	5.13	5.73	6.30
Salinity	32.30	32.75	33.28	33.66	34.07
σ_τ	25.67	25.98	26.33	26.54	26.80
Oxygen, cc pr. l.	7.23	7.27	6.91	6.82	6.64
— saturation %	98.2	100.6	97.5	97.7	96.6
Number of cc examined	50	50	50	50	50
Actinocyclus Ehrenbergii	..	..	..	20	..
Coscinodiscus concinnus	160	..	..	..	..
— radiatus	..	20	..	..	..
— stellaris	..	..	20	20	..
Coscinosira polychorda	..	..	..	..	40
Eucampia groenlandica	..	..	20	..	..
Leptocylindrus minimus	120	..	..	..	..
Navicula gelida var.	..	..	40	..	..
Nitzschia delicatissima	20	..	40	40	..
Skeletonema costatum	1360	..	580	460	100
Thalassiosira decipiens	..	..	..	20	..
— gravida	80	..	..	..	..
Thalassiothrix nitzschioides	160	80	..	..	80
Pleurosigma affine	..	..	20	..	..
Phaeocystis Pouchetii, col. juv.	20	..	..	..	..
Ceratium lineatum	20	..	..	..	..
Dinophysis acuminata	..	20	..	..	..
Laboea constricta	..	..	20	..	..
— vestita	300	80	..	..	..
Lohmanniella oviformis	460	60	20	..	40
Mesodinium rubrum	..	180	..	..	..
Infusoria cetera	60	20	..	..	..
Nauplii	..	..	20	..	..

Tabel XXXIX. 1927. St. 106. March 22th. 9 a. m. Julsund.

Depth	1	10	25	40	75
Temperature	4.82	4.91	4.98	5.09	6.78
Salinity	32.74	32.97	33.03	33.04	33.96
σ_τ	25.93	26.10	26.14	26.15	26.65
P_H	8.19	8.25	8.20	8.16	8.07
Oxygen, cc pr. l.	7.73	7.59	7.55	7.49	6.25
— saturation %	107.6	106.1	105.9	105.2	91.9
Number of cc examined	10	10	10	25	50
Asterionella japonica	500	2700	1400	680	40
Chaetoceras compressum	..	1100	..	..	..
— constrictum	600	..	..	..	..
— convolutum	200	400	600	..	..
— curvisetum	600	1600	..	640	..
— debile	8400	2200	200	2040	..
— decipiens	..	1100	..	400	200
— diadema	400	1200	..	..	..
— furcellatum (spores)	..	4500	..	400	..
— laciniosum	400	..	..	440	..
— simile	..	300	..	..	..
— sociale (spores)	2800	12100	5700	1880	420
Cerataulina Bergonii	..	600	..	40	..
Coscinodiscus concinnus	..	..	..	40	20
— radiatus	..	100	..	..	..
Coscinosira polychorda	1100	300	..	320	20
Eucampia groenlandica	400	700	..	..	..
Lauderia borealis	3100	..	1500	1800	..
— glacialis	..	700	400	200	..
Leptocylindrus minimus	..	..	..	320	..
Navicula directa	100	200	200	..	40
— gelida var.	..	200	300	80	..
Nitzschia Closterium	..	..	..	40	..
— delicatissima	..	1200	700	40	..
— seriata	..	..	300	160	..
Rhizosolenia alata	..	400	..	320	..
— faeroeensis	..	..	200	..	..
Skeletonema costatum	9600	90400	130800	75400	360
Thalassiosira decipiens	..	..	1400	..	..
— gravida	400	4400	3400	1280	120
— nana	..	200	800	..	..
— Nordenskiöldii	..	2600	..	..	sp. 40
Thalassiothrix nitzschioides	400	6600	5600	2880	60
Thalassiosira hyalina	..	..	100	320	..
Phaeocystis Pouchetii	4400	11900	2800	360	..
Podolampas palmipes	..	100	..	..	..
Laboea acuminata	200	..	..	40	..
— strobila	..	100	..	40	..
Mesodinium rubrum	200	100	..	80	..
Amoeba	100	..	..	..	20

Tabel XL. 1927. St. 107. March 22th. Romsdalsfjord.

Depth	1	10	25	40	75	400
Temperature	5.26	5.26	5.24	5.54	7.61	7.08
Salinity	32.77	32.86	32.97	33.06	33.91	34.76
σ_t	25.90	25.97	26.06	26.10	26.49	27.24
P_H	8.18	8.24	8.16	8.15	8.14	8.05
Oxygen, cc pr. l.	7.99	7.81	7.68	7.16	5.89	5.42
— saturation %	112.6	110.2	109.3	101.5	88.2	80.7
Number of cc examined	25	10	10	50 (10)	50	50
Eutreptia Lanowii	40	300	..	..	..	..
Achnanthes taeniata	..	..	2000	..	..	..
Asterionella japonica	600	4900	1200	840	..	..
Chaetoceras boreale	..	..	200	..	..	..
— compressum	..	4300	2900	..	..	..
— curvisetum	1880	19200	8400	2240	..	..
— convolutum	..	200	..	..	..	..
— constrictum	..	1200	500	80	..	..
— debile	18440	81900	144700	3540	..	..
— decipiens	3200	4700	1100	2140	..	..
— diadema	120	3500	4200	..	..	..
— furcellatum (spores)	1760	14400	10100	1660	..	..
— laciniosum	400	4100	900	80	..	..
— simile	120	1000	..	..	..	..
— sociale (spores)	24080	86600	65900	50900	..	..
— teres	..	200	100	40	..	..
Coscinodiscus concinnus	..	80	100	..	..	..
— stellaris	..	100	..	..	..	..
Coscinosira polychorda	620	2700	400	460	..	..
Eucampia groenlandica	280	100	..	40	..	..
Fragilaria oceanica	4000	10100	..	1020	..	..
Cerataulina Bergonii	200	200	..	..	..	..
Lauderia borealis	4400	7030	5900	2560	..	..
— glacialis	120	1100	400	800	..	..
Leptocylindrus danicus	160	1500	..	..	..	..
— minimus	320	1800	900	100	..	..
Navicula gelida var.	240	900	500	280	..	..
Nitzschia Closterium	..	300	100	180	..	..
— delicatissima	2080	10200	2200	3120	160	..
— seriata	240	1500	..	..	..	..
Rhizosolenia alata	100	230	200	220	..	..
— faeroeensis	..	20	..	..	..	..
— fragilissima	320	2500	900	80	..	..
Skeletonema costatum	147920	306000	180800	198200	1720	..
Thalassiosira decipiens	200	800	800	460	20	..
— gravida	5920	9700	6800	1800	20	..
— hyalina	..	1300	..	..	..	..
— nana	..	..	700	..	..	..
— Nordenskiöldii	6160	22300	2200	980	..	..
Thalassiothrix nitzschioides	21640	31700	16400	12260	160	..
Phaeocystis Pouchetii	80	6000	800	40	..	..
Distephanus speculum	40	..	..	20	..	..
Ceratium furca	..	..	40	20	..	..
— lineatum	..	20	..	20	..	..

Tabel XL. 1927. St. 107 (continued).

Depth	1	10	25	40	75	400
Temperature	5.26	5.26	5.24	5.54	7.64	7.08
Salinity	32.77	32.86	32.97	33.06	33.91	34.76
σ_τ	25.90	25.97	26.06	26.10	26.49	27.24
P_H	8.18	8.24	8.16	8.15	8.14	8.05
Oxygen, cc pr. l.	7.99	7.81	7.68	7.16	5.89	5.42
— saturation %	112.6	110.2	109.3	101.5	88.2	80.7
Number of cc examined	25	10	10	50 (10)	50	50
Gonyaulax spinifera	40	..	..	..	..	..
Gymnodinium Lohmanni	120	100	40	40	..	..
— sp.	..	200	..	20	40	..
Oxytoxum gracile	..	..	..	20	..	..
Peridinium depressum	40	20	..	..	..	..
— ovatum	80	..	..	..	..	..
Cyttarocylis denticulata	..	100	..	..	..	..
Laboea acuminata	120	200	..	..	..	..
— conica	240	..	..	..	..	..
— constricta	..	..	..	..	20	..
— strobila	..	200	..	..	..	..
Lohmanniella oviformis	..	100	100	..	..	..
Mesodinium rubrum	720	900	..	..	..	..
Ptychocylis urnula	..	100	..	..	..	..
Tintinnus acuminatus	..	..	..	..	20	..
Infusoria cetera	40	100	..	40	40	..
Fritillaria borealis	..	100	300	20	..	..
Oikopleura sp.	..	..	..	20	..	..

Tabel XLI. 1927. St. 108. March 22th. Romdalsfjord.

Depth	1	10	25	40	75
Temperature	5.14	4.92	5.06	6.93	7.82
Salinity	31.27	32.45	32.75	33.35	34.16
σ_τ	24.73	25.69	25.91	26.15	26.66
P_H	8.22	..	..	..	8.13
Oxygen, cc pr. l.	7.83	8.11	7.81	6.17	5.73
— saturation %	111.4	112.8	109.4	90.6	86.3
Number of cc examined	25	25	25	50	50
Eutreptia Lanowii	..	80	..	..	..
Chaetoceras atlanticum	80	120	..	..	..
— compressum	..	2080	..	..	..
— constrictum	80	..	..	..	..
— curvisetum	160	..	..	..	..
— debile	840	2280	240	..	..
— decipiens	1720	960	4960	180	..
— laciniosum	480	240	80	..	..
— Schüttii	120	160	..	..	..

Tabel XLI. 1927. St. 108 (continued).

Depth	1	10	25	40	75
Temperature	5.14	4.92	5.06	6.93	7.82
Salinity	31.27	32.45	32.75	33.35	34.16
σ_t	24.73	25.69	25.91	26.15	26.66
P_H	8.22	..	..	..	8.13
Oxygen, cc pr. l.	7.83	8.11	7.81	6.17	5.73
— saturation %	111.4	112.8	109.4	90.6	86.3
Number of cc examined	25	25	25	50	50
Chaetoceras simile	..	..	160	80	..
— sociale	..	2720	1120	200	..
— teres	40	..	..	..	..
Cerataulina Bergonii	600	360	160	..	..
Coscinosira polychorda	920	880	1360	240	..
Lauderia borealis	440	2000	2080	240	..
Leptocylindrus minimus	240	..	..	..	..
Navicula gelida var.	40	120	40	100	..
Nitzschia Closterium	..	..	..	20	..
— delicatissima	25920	2520	4120	380	60
— seriata	..	200	..	..	..
Rhizosolenia alata	80	120	240	40	..
— faeroeensis	..	120	..	..	..
— Shrubsolei	..	40	..	..	..
Skeletonema costatum	380200	32160	27560	5140	1840
Thalassiosira decipiens	120	200	11360	700	..
— gravida	40	2320	1200	540	..
— hyalina	..	360	..	..	..
— Nordenskiöldii	120	800	..	..	..
Thalassiothrix nitzschioides	9120	5760	5880	540	..
Coscinodiscus radiatus	..	40	..	..	..
Phaeocystis Pouchetii col.	..	920	440	60	..
Distephanus speculum	40	..	40	..	..
Ceratium longipes	..	..	40	..	..
— lineatum	..	40	..	..	..
Dinophysis acuminata	..	40	..	..	..
Peridinium ovatum	..	..	40	..	..
— depressum	80	..	..	..	..
Gonyaulax spinifera	40	..	..	..	..
Gymnodinium Lohmanni	..	160	..	..	..
Pterosperma dictyon	40	..	..	..	..
— Vanhöffeni	..	..	40	..	..
Tintinnopsis ventricosa	..	40	..	..	..
Cyttarocylis denticulata	..	160	..	..	20
— norvegica	40	..	160	..	..
Laboea acuminata	40	320	160	40	..
— strobila	40	680	..	..	..
— vestita	..	40	..	20	..
— sp.	120	..	..	..	..
Lohmanniella oviformis	240	200	40	40	..
— spiralis	80	..	..	..	..
Mesodinium rubrum	..	160	240	60	20
Infusoria cetera	40	..	..	20	40
Nauplii	..	..	80	..	..

Tabel XLII. 1927. St. 109. March 28th. 7 a. m. 51′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	8.02	8.09	8.21	8.38	8.38
Salinity	35.21	35.21	35.23	35.25	35.30
σ_t	27.46	27.45	27.44	27.42	27.47
P_H	8.10	8.13	8.18	8.15	8.18
Oxygen, cc pr. l.	6.60	6.49	6.41	6.43	6.38
— saturation %	100.6	99.1	98.9	98.5	98.9
Number of cc examined	10	10 (50)	50	50	50
Asterionella japonica	330600	271300	109920	1820	..
Chaetoceras boreale	..	600	..	..	..
— constrictum	..	60	..	..	..
— curvisetum	..	..	40	..	..
— debile	500	1300	200	..	200
— decipiens	..	..	160	..	..
— laciniosum	3100	900	180	..	..
— pelagicum	..	..	120	..	140
— scolopendra	..	..	140	..	..
— teres	..	600	100	..	..
Coscinodiscus excentricus	..	..	..	20	20
— radiatus	..	..	20	..	..
Coscinosira polychorda	..	40	..	..	..
Cerataulina Bergonii	..	100	280	..	..
Lauderia glacialis	300	700	340	..	..
Navicula gelida var.	900	200	300	20	20
Nitzschia Closterium	100	..	40	..	..
— delicatissima	1100	1700	620	..	140
Rhizosolenia faeroeensis	400	100	240	..	..
— semispina	500	100	180	..	..
— Stolterfothii	..	..	160	..	..
Skeletonema costatum	58700	68300	25880	380	120
Thalassiosira decipiens	3000	2500	1140	..	100
— gravida	400	..	60	..	..
— nana	13200	7900	2200	..	..
— Nordenskiöldii	18700	23200	13960	..	..
Thalassiothrix nitzschioides	300	800	120	..	..
Thalassiosira bioculata	..	..	..	..	260
Distephanus speculum	100	100	..	..	..
Ceratium fusus	100	20	..	..	..
Oxytoxum gracile	200	..	..	..	..
Peridinium ovatum	..	20	..	..	..
Laboea conica	100	..	..	..	..
— emergens	200	100	..	20	20
Lohmanniella oviformis	300	500	..	..	..
Mesodinium rubrum	100	100	..	..	..
Tintinnus acuminatus	..	..	..	..	20
Nauplii	..	100	20	..	20

Tabel XLIII. 1927. St. 110. March 28th. 10 a. m. 44′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.70	6.71	7.43	7.77	8.08
Salinity	34.45	34.49	34.85	34.99	35.03
σ_t	27.05	27.08	27.26	27.32	27.31
$P_{\bar{H}}$	8.28	8.25	8.12	8.05	8.01
Oxygen, cc pr. l.	7.61	7.49	6.62	6.39	6.36
— saturation %	112.0	110.5	99.2	96.7	96.9
Number of cc examined	5	5	25	25	50
Asterionella japonica	1507800	1218400	358920	76960	19360
Chaetoceras boreale	..	800	..	..	..
— compressum	16000	..	..	..	..
— constrictum	3000	7800	1200	80	..
— debile	27200	12600	2120	..	180
— decipiens	1400	..	160	520	..
— diadema	1400	3200	360	..	..
— didymum	..	1800	..	..	..
— laciniosum	7800	4800	1420	640	760
— Schüttii	..	3200	..	..	..
— scolopendra	13200	4000	2080	480	..
— simile	..	400	..	80	60
— sociale	800	2400	1200	..	..
— teres	1400	1400	320	..	..
Coscinodiscus radiatus	..	..	..	..	20
Coscinosira polychorda	..	..	40	..	40
Lauderia glacialis	1400	1400	240	480	120
Leptocylindrus danicus	800	..	..	..	..
— minimus	1600	..	..	..	..
Navicula gelida var.	5200	4200	1960	520	160
Nitzschia Closterium	400	400	120	..	..
— delicatissima	4600	2200	600	200	180
— seriata	2200	400	880	..	..
Rhizosolenia faeroeensis	3200	600	280	120	220
— fragilissima	1400	2800	200	..	..
— semispina	400	1400	200	200	60
— Stolterfothii	..	..	120	..	..
Skeletonema costatum	47200	77400	29240	9400	6020
Thalassiosira decipiens	3600	6000	3560	680	640
— gravida	1000	600	360	120	..
— nana	18200	10400	2400	400	780
— Nordenskiöldii	120400	89200	14440	6080	2040
Thalassiothrix nitzschioides	6800	13200	1760	320	160
Ceratium fusus	..	200	..	..	..
Oxytoxum diploconus	..	..	..	40	..
— gracile	200	..	80	80	20
Gymnodinium Lohmanni	200	..	..	..	20
Laboea conica	200	..	..	..	..
Lohmanniella oviformis	..	800	40	..	20
Ptychocylis urnula	200	..	..	..	..
Amoeba sp.	27800	35800	?	?	?

Tabel XLIV. 1927. St. 111. March 28th. 2 p. m. 32′ NW. Björnsund.

Depth	1	10	25	40	75
Temperature	6.64	6.82	6.94	6.99	7.07
Salinity	34.42	34.47	34.67	34.74	34.99
σ_t	27.03	27.09	27.19	27.24	27.35
P_H	8.25	8.24	8.01	8.06	8.09
Oxygen, cc pr. l.	7.58	7.48	6.57	6.79	6.25
— saturation %	111.5	109.8	97.5	100.9	94.2
Number of cc examined	5	5	5	25	25
Asterionella japonica	1535200	1712000	177400	150480	1720
Chaetoceras boreale	1200	1200	800	..	..
— compressum	..	3400	..	..	..
— constrictum	3200	2200	..	1680	..
— debile	12200	16400	..	1040	..
— decipiens	..	..	2800	..	..
— laciniosum	2200	12800	800	480	..
— scolopendra	..	2800	..	..	..
— simile	..	200	..	..	..
— sociale	5600	15600	..	..	..
— teres	..	..	600	120	..
Cerataulina Bergonii	600	..	..	..	..
Coscinosira polychorda	2000	1000	200	1400	..
Lauderia borealis	..	1600	..	..	..
— glacialis	1000	6200	1000	720	..
Navicula gelida var.	2400	3600	600	360	..
Nitzschia Closterium	800	..	..	..	..
— delicatissima	9000	7600	2000	1200	80
— seriata	2400	2200	..	..	..
Rhizosolenia faeroeensis	400	1600	600	200	..
— fragilissima	..	3200	..	80	..
— semispina	400	800	800	320	..
Skeletonema costatum	233400	201600	216800	180640	4240
Thalassiosira decipiens	1600	8400	600	2200	..
— gravida	3200	1600	2600	2080	..
— nana	6400	13800	1000	1160	..
— Nordenskiöldii	16400	75200	8800	9960	520
Thalassiothrix nitzschioides	..	800	..	1040	..
Dictyocha fibula	..	..	..	40	..
Distephanus speculum	200	..	..	..	..
Ceratium fusus	..	..	..	40	..
— intermedium	..	..	..	40	..
— lineatum	..	..	..	40	..
Dinophysis acuminata	200	..	..	..	..
Gymnodinium Lohmanni	..	400	..	..	..
Torodinium robustum	..	200	..	..	..
Amoeba	7200	4800	1800	1480	..
Laboea acuminata	..	200	..	..	..
Lohmanniella oviformis	400	400	..	80	..
Laboea emergens	..	..	..	..	40
Ptychocylis urnula	..	200	..	40	..
Nauplii	..	..	..	40	..

Tabel XLV. 1927. St. 112. March 28th. 17′ NW. Björnsund.

Depth	1	10	25	40	60
Temperature	5.36	5.13	5.58	5.93	6.37
Salinity	32.90	33.08	33.38	33.91	34.23
σ_t	25.99	26.16	26.51	26.72	26.92
P_H	8.26	8.19	8.13	8.10	8.13
Oxygen, cc pr. l.	7.70	7.69	7.21	6.88	6.70
— saturation %	109.1	108.1	102.8	99.1	97.8
Number of cc examined	5	5	10	10	50
Asterionella japonica	93800	145400	1198900	285300	213000
Biddulphia aurita	..	..	..	..	80
Cerataulina Bergonii	..	..	100	..	..
Chaetoceras atlanticum	..	..	200	..	..
— boreale	..	..	200	300	100
— compressum	2800	4600	..	..	340
— constrictum	2400	3600	400	..	60
— convolutum	..	..	..	..	40
— debile	..	..	2800	..	..
— decipiens	600	..	1200	..	480
— diadema	..	..	800	1600	..
— laciniosum	..	..	600	800	360
— scolopendra	..	..	1600	1600	..
— sociale	..	..	2100	2000	..
— teres	..	2400	3100	400	80
Coscinosira polychorda	..	..	200	100	100
Navicula directa	..	..	..	..	20
— gelida var.	..	1000	3000	600	420
Nitzschia Closterium	..	..	..	..	40
— delicatissima	..	..	700	100	..
— seriata	..	..	400	..	..
Lauderia glacialis	..	..	600	..	40
Rhizosolenia faeroeensis	200	..	400	300	80
— fragilissima	1600	..	..	..	40
— semispina	200	200	700	400	240
Skeletonema costatum	..	1600	18100	7000	7160
Thalassiosira decipiens	..	..	2300	500	220
— gravida	..	..	..	..	280
— Nordenskiöldii	9000	46200	59500	7700	4980
Thalassiothrix nitzschioides	..	..	..	..	40
Ceratium bucephalum	..	..	..	100	..
— longipes	200	..	..	..	..
— intermedium	..	..	..	..	20
Gyrodinium sp.	..	..	100	..	..
Oxytoxum gracile	..	..	..	100	..
Peridinium achromaticum	..	..	..	..	20
— depressum	200	200	..	..	..
— ovatum	200	..	100	..	..
— pellucidum	..	..	100	..	..
Prorodinium robustum	..	..	100	..	..
Amoeba sp.	..	200	1400	3200	6000
Tiaboea acuminata	..	..	100	..	..
Lohmanniella oviformis	200	1600	300	..	20

Tabel XLVI. 1927. St. 113. March 28th. 5′ NNW. Björnsund.

Depth	1	10	25	40	75
Temperature	5.13	5.07	5.19	5.22	5.29
Salinity	33.08	33.10	33.33	33.37	33.44
σ_t	26.16	26.18	26.35	26.37	26.40
P_H	8.25	8.23	8.19	8.15	8.18
Oxygen, cc pr. l.	7.84	7.52	7.29	7.29	7.29
— saturation %	110.5	105.6	103.0	103.1	103.2
Number of cc examined	25 (5)	25 (5)	25 (5)	25 (5)	50
Actinocyclus Ehrenbergii	40	..	..	40	..
Asterionella japonica	424800	758600	874000	424800	265800
Biddulphia aurita	..	..	..	40	..
Cerataulina Bergonii	..	80	..	..	140
Chaetoceras boreale	120	760	640	80	140
— compressum	..	..	240	..	440
— constrictum	1360	800	1120	840	140
— curvisetum	..	80	1080	760	..
— debile	800	360	2360	6800	180
— decipiens	360	..	120	..	..
— diadema	280	..	..	440	1260
— didymum	960	..	..	..	..
— laciniosum	640	440	80	..	500
— scolopendra	840	480	..	..	160
— sociale sp.	..	240	..	80	..
— teres	240	200	120	120	100
Coscinodiscus radiatus	..	40	..	..	20
Coscinosira polychorda	..	120	160	240	..
Eucampia Zoodiacus	..	..	..	240	..
Lauderia borealis	..	40	80	360	..
— glacialis	40	40	200	280	..
Leptocylindrus danicus	..	160	..	40	140
Navicula directa	..	40	160	..	..
— gelida var.	160	280	320	880	160
Nitzschia Closterium	40	40	40	..	..
— delicatissima	..	200	80	240	60
— seriata	320	400	80	360	60
Rhizosolenia alata	..	..	..	80	..
— faeroeensis	200	240	200	560	180
— fragilissima	120	200	..	..	360
— semispina	320	880	680	600	260
— setigera	40	..	..	..	..
Skeletonema costatum	1000	5360	11480	8840	500
Thalassiosira gravida	40	120	120	520	140
— Nordenskiöldii	6120	5080	3920	3400	6400
Thalassiothrix longissima	..	80	..	..	..
— nitzschioides	160	440	1340	..	20
Ceratium lineatum	..	..	..	40	..
— longipes	..	120	..	..	..
Dinophysis acuminata	..	..	40	..	..
Exuviaella sp.	..	80	..	40	..
Gymnodinium Lohmanni	..	..	..	..	140
Peridinium crassipes	..	..	..	..	40
— depressum	40	..	..	..	80
— Steinii	40	40	..	..	..
— sp.	120	80	40	80	60
— ovatum	..	..	..	..	40

Tabel XLVI. 1927. St. 113 (continued).

Depth	1	10	25	40	75
Temperature	5.13	5.07	5.19	5.22	5.29
Salinity	33.08	33.10	33.33	33.37	33.44
σ_t	26.16	26.18	26.35	26.37	26.40
P_H	8.25	8.23	8.19	8.15	8.18
Oxygen, cc pr. l.	7.84	7.52	7.29	7.29	7.29
— saturation %	110.5	105.6	103.0	103.1	103.2
Number of cc examined	25 (5)	25 (5)	25 (5)	25 (5)	50
Cyttarocylis denticulata	80	..	..	..	20
— norvegica	..	40	..	..	..
Laboea acuminata	40	..	..	..	40
— conica	..	..	..	..	220
— vestita	..	..	..	..	40
Lohmanniella oviformis	..	..	..	40	60
Mesodinium rubrum	120	..	..	..	380
Ptychocylis urnula	40	..	40	..	80
Nauplii	..	..	..	..	40
Fritillaria borealis	..	40	..	..	20

Tabel XLVII. 1927. St. 114. March 28th. Julsund.

Depth	1	10	25	40	75
Temperature	5.08	5.07	5.08	5.18	5.85
Salinity	32.68	32.84	33.08	33.26	33.75
σ_t	25.85	25.98	26.17	26.30	26.61
P_H	8.21	8.16	8.18	8.19	8.13
Oxygen, cc pr. l.	7.63	7.55	7.41	7.37	6.75
— saturation %	106.9	105.9	104.2	104.0	97.0
Number of cc examined	25	25	50	25 (5)	50
Actinocyclus Ehrenbergii	..	..	..	..	20
Asterionella japonica	280	5000	3100	65000	55060
Cerataulina Bergonii	40	120	100	..	20
Chaetoceras atlanticum	..	..	..	200	140
— boreale	240	..	120	..	..
— compressum	..	..	680	1520	..
— constrictum	..	80	..	1000	100
— convolutum	280	..	..	..	..
— curvisetum	1840	160	580	520	..
— debile	160	3800	6140	21680	..
— decipiens	1840	1920	1220	120	280
— diadema	160	..	40	..	..
— furcellatum	160	..	40	80	..
— laciniosum	280	120	40	680	..
— Schüttii	360	..	..	..	..
— scolopendra	..	..	..	..	80
— simile	120	..	..	..	..
— sociale	520	3120	900	1400	1180
— teres	..	..	..	40	20
Coscinodiscus concinnus	40	..	40	80	..
— radiatus	..	..	..	40	20
Coscinosira polychorda	160	200	360	40	160

Tabel XLVII. 1927. St. 114 (continued).

Depth	1	10	25	40	75
Temperature	5.08	5.07	5.08	5.18	5.85
Salinity	32.68	32.84	33.08	33.26	33.75
σ_t	25.85	25.98	26.17	26.30	26.61
P_H	8.21	8.16	8.18	8.19	8.13
Oxygen, cc pr. li.	7.63	7.55	7.41	7.37	6.75
— saturation %	106.9	105.9	104.2	104.0	97.0
Number of cc examined	25	25	50	25 (5)	50
Lauderia borealis	1000	2280	2680	3600	140
— glacialis	..	80	..	..	40
Leptocylindrus danicus	40	..	..	..	..
— minimus	..	..	320	..	..
Navicula directa	..	40	40	40	40
— gelida var.	..	40	20	280	560
Nitzschia Closterium	..	..	..	80	..
— delicatissima	400	720	140	360	..
— . seriata	..	200	180	240	180
Rhizosolenia alata	80	320	80	240	160
— calcar avis	..	..	..	..	20
— faeroeensis	..	..	..	80	100
— fragilissima	..	40	..	160	40
— semispina	..	..	80	80	260
Skeletonema costatum	11040	36600	30640	22280	12440
Thalassiosira bioculata	..	80	..	..	..
— decipiens	..	..	20	..	20
— gravida	760	2000	2540	2960	180
— Nordenskiöldii	..	640	580	440	1040
Thalassiothrix nitzschioides	1760	2600	3840	5520	1420
Distephanus speculum	..	..	20	..	..
Ceratium bucephalum	..	..	..	..	20
— lineatum	..	40	20	..	..
— longipes	..	..	60	..	..
— tripos	40	40	..	..	..
Dinophysis acuminata	..	40	40	..	..
Gymnodinium Lohmanni	..	80	..	80	..
Peridinium depressum	..	40	20	..	..
— ovatum	..	80	60	..	..
— pallidum	..	..	40	..	..
— Steinii	..	80	..	..	..
— sp.	40	..	60	..	..
— pellucidum	40	40	..	..	..
Amoeba sp	..	..	..	80	..
Cyttarocylis denticulata	40	..	20	40	..
— norvegica	40	40	20	..	..
Laboea crassula	..	40	..	..	..
Lohmanniella oviformis	40	80	..	40	..
— spiralis	..	40	..	..	..
Mesodinium rubrum	..	40	..	..	20
Ptychocylis urnula	40	..	..	40	..
Tintinnus acuminatus	..	40	..	..	..
Nauplii	..	40	40	..	..
Fritillaria borealis	40	..	..	40	..

Corrections.

p. 30, l. 10 from bottom for "change able" read "changeable". p. 81, l. 1 from top for "VIII" read "XVIII".

COPEPODS

FROM THE

"MICHAEL SARS" EXPEDITION, 1924

BY

LEIF STÖRMER

COPENHAGUE — IMPRIMERIE BIANCO LUNO

At the invitation of Professor, Dr. Johan Hjort, I accompanied his expedition to Greenland, with the $^{s}/_{s}$ "Michael Sars", in the summer of 1924.

The present work is the result of my investigation, made at the suggestion of Professor Hjort, of the material of copepods collected in the course of the expedition.

The capture of copepods was effected by vertical hauls with the closing net, and horizontal hauls with the tow net. The systematic investigation was restricted to the vertical hauls.

The nets used for the vertical hauls were of 70 cm. diameter, with a mesh at the bottom of $32^{1}/_{2}$ threads per cm. The sifting capacity varies greatly; a rich haul of phytoplankton may render the silk almost impermeable.

In making the investigations, Professor Hjort advised me to use the method of counting 100 specimens of copepods from each sample.

Dr. Willy (1919) has employed this method. It affords some idea as to the proportionate numbers of the various species of copepods. I have not here entered upon any mathematical discussion as to the limits of error in the various cases.

By way of checking the method of counting employed, 100 specimens were taken out and counted, the process being repeated six times for each sample. Table A shows the numbers of the different species from the six counts.

In the investigation of the copepod material, from Station 7 onwards, a somewhat coarser silk was used as a sieve in taking out the 100 copepods. The width of mesh of this silk was 23 threads per cm. whereas that of the net was $32^{1}/_{2}$ threads per cm. In the table, the three first counts were taken after the method used at Stations 1—6; the three last counts show the method mostly used for taking out the copepods, i. e. in the samples from Station 7—74 inclusive.

The method of counting 100 specimens gives us the relative quantity of the different species of copepods. It tells us nothing as to the absolute quantity. In order to form an idea as to this absolute quantity, measurements of volume were employed. The volume was measured in measuring cylinders, after the catch

Table A. St. 2. 25—0 m. Vertical haul.

	1st method			2nd method		
Calanus finmarchicus St. I	..	..	..	2	..	..
— — - II	..	..	1	..	1	..
— — - III	1	..	..	..	..	..
— — - IV	2	4	2	2	6	4
— — - V	31	28	28	17	21	13
— — - VI	12	12	12	10	15	6
Pseudocalanus minutus - I—III	..	..	..	3	1	1
— — - IV	..	..	..	1	1	2
— — - V	21	20	19	6	9	9
— — - VI	..	..	..	13	8	11
Microcalanus pygmæus	2	2	1	4	4	2
Copepodites of small calanids	1	..	3	..	..	..
Metridia longa	..	..	..	1	..	..
— lucens	2	6	1	1	1	..
Oithona helgolandica	27	28	33	39	32	48
— spinirostris	1	..	..	..	1	1
Nauplii	..	..	..	1	..	

had sunk. Larger creatures, such as the larger euphausidæ and medusæ were removed during measurement. The measurements of volume on sinking were in many cases useless. In addition to the copepods there were numerous animals and plants which often took up the greater part of the volume. In several instances, the haul consisted of a single gelatinous mass of medusæ residue. In the table for counts of *Calanus finmarchicus*, the volume measurements are noted. Samples from the same depth, at one and the same station, may vary greatly in volume. Figs. 5 and 8 shows the volumes as a graph.

In the tables of countings, I have introduced the terms nauplii and copepodites of macro and microcalanides. By copepodites of microcalanides I mean copepodites of calanides about the size of *Pseudocalanus minutus* or less. The nauplii need not be calanides, but may also belong to other copepods. Macrocalanides are those larger than *Pseudocalanus*.

I should like here to express my very sincere thanks to Professor Johan Hjort for his great kindness in affording me this opportunity of accompanying the expedition and dealing with the copepod material. I also wish to thank him for valuable advice in the execution of the work, and for the interest he has evinced throughout.

I am likewise greatly indebted to Professor H. H. Gran for having kindly read through my MS. Dr. Martens has very courteously furnished me with hydrographical sections from the waters investigated.

I also wish to thank stud. real. J. D. Sømme for all his kind assistance in the course of this work. Stud. real. J. Ruud has given me many useful hints.

Calanus Finmarchicus Gunnerus.

Calanus finmarchicus in the course of its development from the ovum, passes through 6 nauplii stages and 5 copepodite stages before reaching the last mature stage.

The nauplius stage has recently been investigated by M. Lebour (1916).

The copepodite stages have already been investigated by Kröyer (see With 1915 p. 12). Gran (1902) distinguished the copepodite stages by measurements of length.

In the present work, I have used Damas' system (1905 p. 8) for determination of the individual copepodite stages. The number of thoracic segments in I—III is altered according to M. Lebour (1916).

Tabel B. Copepodid Stages of Calanus (Damas 1905).

Stages	Thoracic segments	Abdominal segments	Pairs of legs
I.....	3	2	2 and rudiments of third pair
II.....	4	2	3 - — - fourth -
III.....	5	2	4 - — - fifth -
IV	5	3	5
V	5	4	5
VI	5	4	5
	5	5	5

According to Oberg (1906 p. 63) and Claus (1863 p. 81) there should be only one abdominal segment on the 2 first copepodite stages (see Kraefft 1910 p. 66).

The nauplii of the copepods are still very little known. Many of the important larger copepods' nauplii have, as far as I am aware, not yet been described. I have not considered it in accordance with the plan of this work to give any detailed determination of the nauplii. All nauplii are therefore taken together in the tables.

In some few pure samples, however, where we have small copepodites of *Cal. fin.* and many nauplii, these can be referred with a great degree of certainly to *Cal. fin.*

The individual copepodite stages are separated in the counts. As regards the smallest copepodite stages, it was in many cases difficult to distinguish between *Cal. fin.* and *Cal. hyperboreus.* This is referred to again under *Calanus hyperboreus.* *Calanus helgolandicus* was not observed in the counts.

Variation in size of *Calanus finmarchicus.*

In counting the material from the "Michael Sars" expedition of 1924, the different copepodite stages were separated, and in addition, a number of specimens were measured, as there was found to be a marked variation in the sizes of one and the same stage. It has long been known that the size of *Calanus fin.* varies a great deal. GRAN (1902 p. 60) has described this phenomenon from the Norwegian Sea: "Im Sommer sind die verschiedenen Entwicklungsstadien jedes für sich kleiner als im Frühling". Later, p. 64, he says: "Eine Erhöhung der Temperatur beschleunigt die Entwicklung, ergiebt aber kleinere Individuen, die einzelnen Schalenabstreifungen und die Geschlechtsreife treten nämlich dann schon mit kleineren Körperdimensionen ein". MRAZEK (1902) found very great variation in the size of *Cal. fin.* in arctic waters. He cannot determine, from his material, whether the variation takes place within one race, or whether larger individuals have been introduced. DAMAS et KOEFOED (1908—09, p. 382—383) likewise refer to this feature. They give the limits of variation for length of *Cal. fin.* St. VI ♀ for the Arctic waters as between 3.2 and 5.4 mm. The length of the cephalothorax (according to DAMAS et KOEFOED = total length minus abdomen) varies between 2.7 mm. and 4.2 mm. WITH (1915 p. 15) gives the greatest length for *Cal. fin.* St. V in Davis Strait as 4.8 mm. WILLY (1919 p. 184—185) has found a similar variation in Canadian waters, near the Gulf of St. Lawrence. The variation of St. V ranges from 2.25 to 4.9 mm. (measurements from the front of the head to the end of the caudal fork). One station (89) with low temperature and salinity, yielded large specimens of St. IV—VI. Another station with higher temperature and salinity yielded small specimens of St. IV—VI. ADLER and JESPERSEN (1920) have gone very closely into the question of size variation in copepods. They have investigated the variation in length of: *Pseudocalanus elongatus* = *minutus*, *Temora longicornis*, and *Calanus finmarchicus* in Jutland waters, and have shown that there is an annual variation in the size, the length being less in summer than in spring. This decrease in size during summer they find also in the copepodite stages of *Cal. fin.* The larger individuals do not represent an immigrant element from colder waters; ADLER and JESPERSEN consider that salinity, nourishment and age are of little importance as causes of seasonal variation. They have investigated waters where the salinity is, practically speaking, constant. Possibly it may be of some importance in other places where it is subject itself to considerable variation. Temperature is the most important factor. They write, p. 23 "On trouve donc que, dans les grandes lignes, la taille moyenne du copépode est inversement proportionelle à la temperature de l'eau". This is the same result as GRAN arrived at. We must assume that no perceptible increase of length takes place within the copepodite stage.

The present material from the "Michael Sars" expedition includes samples of *Cal. fin.* from very different water layers. The variation in size of *Cal. fin.* was,

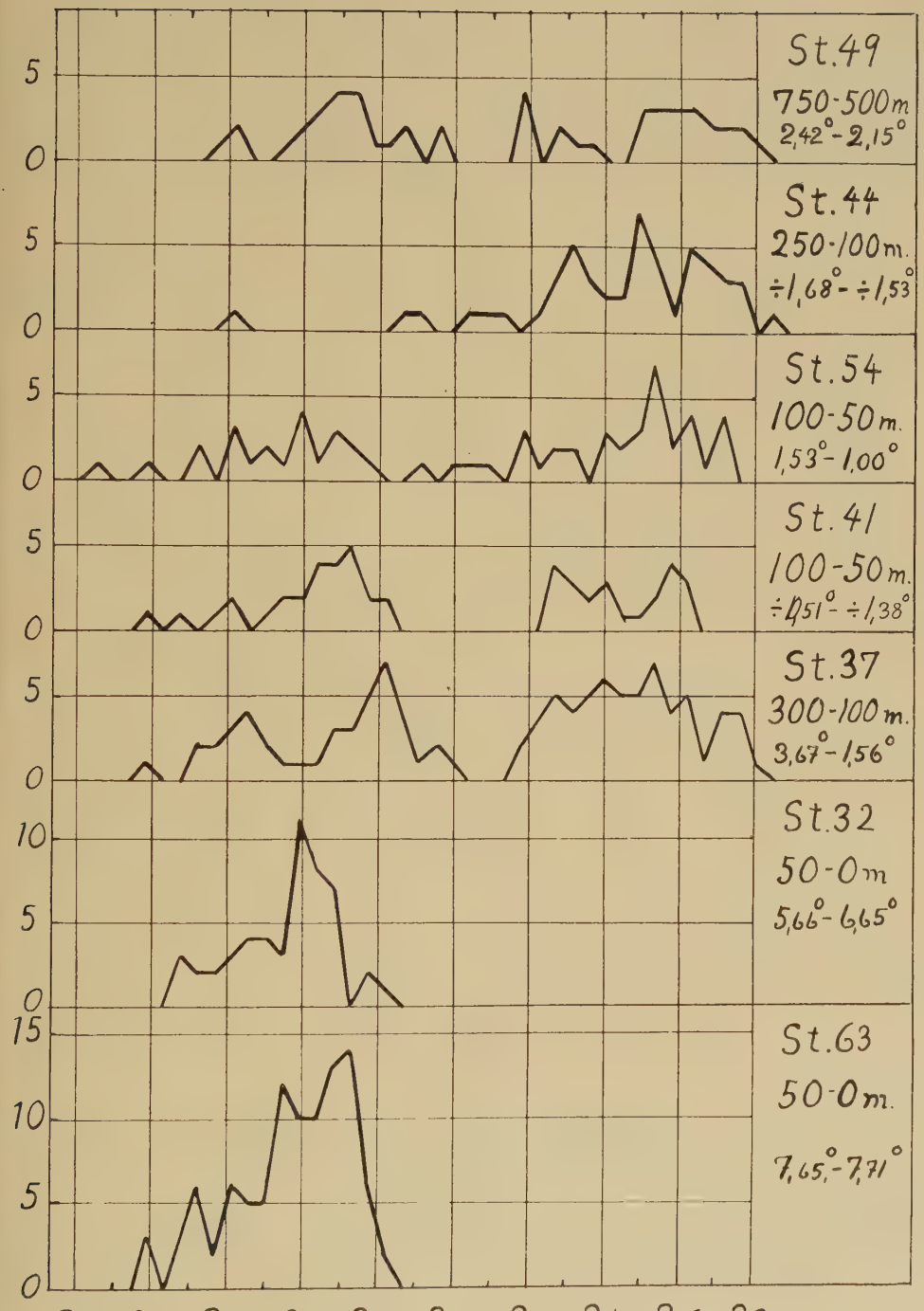

Fig. 1. Length measurements of *Calanus finmarchicus* (Stage V) from stations on the West Coast of Greenland.

as might be expected, greatest at the northern stations, off the coast of Greenland VI ♀ occurred comparatively rarely; I therefore preferred for the most part to measure St. V, which was the most common. The measurements indicate length of the entire animal minus abdomen, answering to the cephalothorax in Damas and Koefoed, Adler and Jespersen. The measurements were made with a Leitz micro-

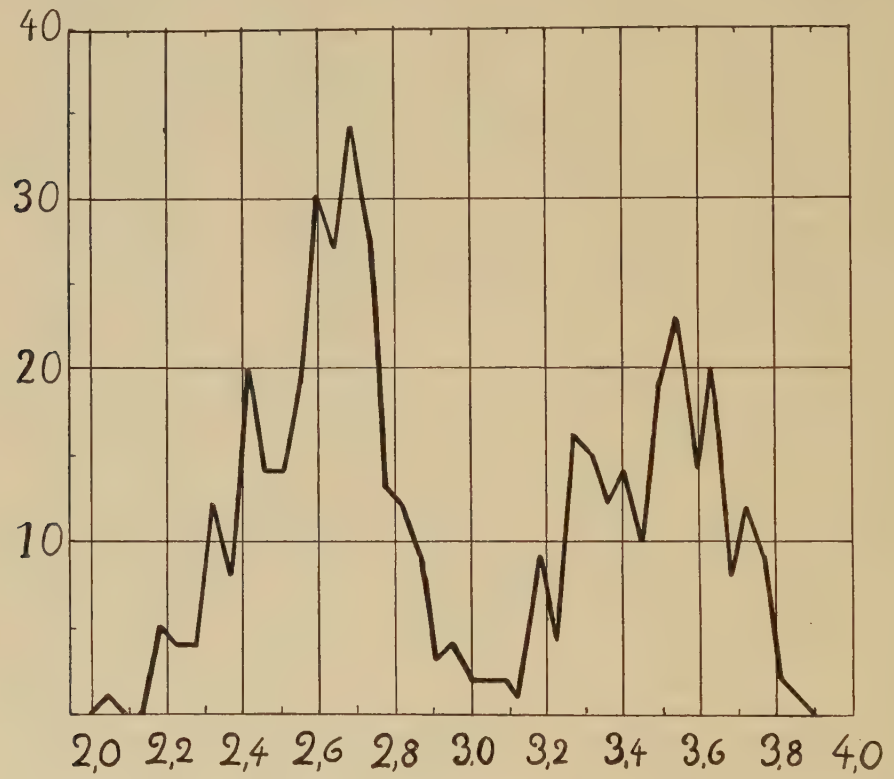

Fig. 2. Length measurements of *Calanus finmarchicus* (Stage V) from stations on the West Coast of Greenland.

scope, objective 3 without front lens, ocular 2 with measurement scale, 1 division line = 0.046 mm.

A length between two lines was raised to the higher of the two values. A number of specimens were measured from each sample selected. In the curves for size distribution, (Figs. 1, 2, 3) the abscissa indicates the length of the individuals measured in mm. and the ordinate the number of individuals of each length. Fig. 1 gives the curve for length of St. V at various stations on the west coast of Greenland and in Davis Strait. In Fig. 2, all measurements from Fig. 1 are taken together. The resultant curve in Fig. 2 shows, not one, but two distinct maxima. There are

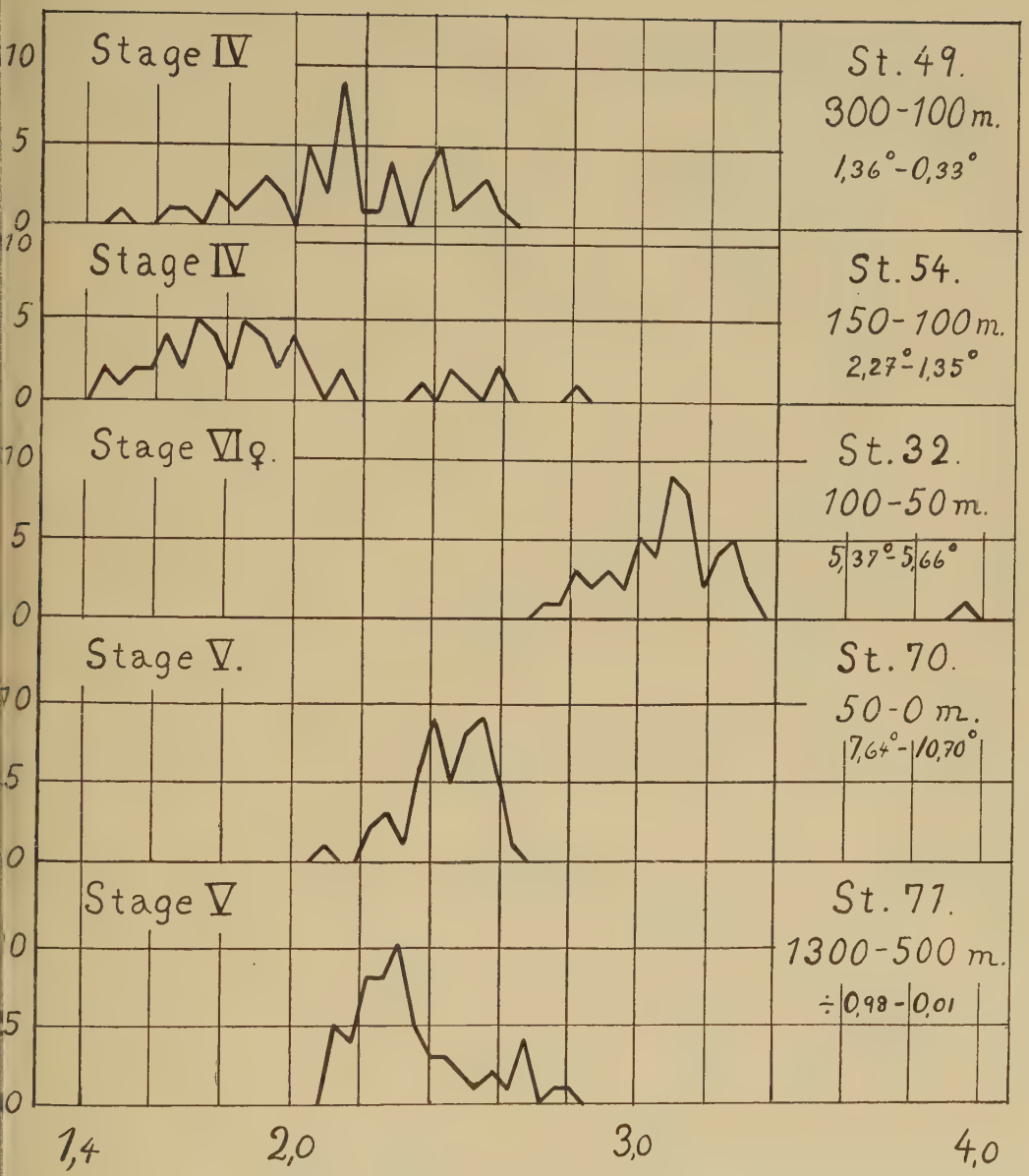

Fig. 3. Measurements of *Calanus finmarchicus*.

thus, in these waters, two separate and distinct sizes of St. V of *Calanus finmarchicus*. In Fig. 1, where the measurements from the individual stations are given we see that there are but few transition sizes between the two commonly occurring. Fig. 1 shows that the coldest station, 44, yielded almost exclusively large specimens. The figure shows the measured temperatures at the bottom and the top of the

haul. St. 54 has mostly large specimens, but also some small ones. St. 49, 41, 37, have about equal numbers of the two sizes. The transition form was not measured at these stations. The southern stations, 32, 63, show only small specimens. We see, then, how the large specimens in the colder water to the north gradually give place to the smaller ones in the warmer water to the southward.

No attempt at explanation of this phenomenon will here be made. The point will be further discussed in connection with the geographical distribution of *Cal. fin.* in these waters.

The variation interval for the 2 sizes is, as will be seen from Figs. 1 and 3, more or less the same, i. e. abt. 0.6—0.7 mm. The measured specimens from of St. V from Stations 70 and 71 east of the Færoes are somewhat smaller than the small forms from Greenland. The specimens from Stations 70 and 71 (see Fig. 3) show a similar interval of variation to that for the Greenland specimens. St. VI♀ from Station 32 shows almost exactly the same variation interval as St. V from the same station. Tables 35—36 in Adler and Jespersen (1920) for length of *Cal. fin.* St. V—VI♀ show that where more than 50 specimens were measured, the variation in length is 0.6—0.8 mm. This answers well to the values found for each of the two sizes in Greenland waters, and for the measured specimens from east of the Færoes. Among St. VI♀ from Station 32 there is also one large specimen corresponding to the large ones of St. V. The large specimen exhibited a morphological approximation to *Calanus hyperboreus*. The posterior thoracic segment was not so evenly rounded as in the ordinary *Cal. fin.*, but had no distinct spines. At the stations farther north, I noticed in my counts VI♀♀ of a total length of 5 mm. These should correspond to the large specimens of St. V. St. IV was measured from Station 49 (300—100 m.) (see Fig. 3). The resultant curve for these two measurements shows no distinct division into two sizes. The curve Fig. 3 for Station 54 has some indication of a division into two sizes, but they are connected up by the specimens from Station 49. There is thus an essential difference in the size variation of St. IV and St. V. Station 49, the coldest station, shows the largest specimens. The variation interval for St. IV is considerably greater than for the large or small forms of St. V.

Geographical distribution.

The stations of the "Michael Sars" from the cruise in 1924 lie scattered over a wide field. The different areas may be roughly distinguished as follows:

1) Stations in the southern part of the Norwegian Sea.
2) South of Iceland.
3) Off the coast of Greenland.

In addition to these, we may note a number of scattered, but faunistically related Atlantic stations.

The individual stations may be taken briefly.

Station 2 lies in on the bank off the coast of Norway. The samples are poor. *Cal. fin.* occurs to the amount of about 60 %. There are most of St. V, but also a number of St. VI. No trace of spawning is observed until we get out on to the edge. Station 1 shows all stages upwards. St. 3 likewise, though to a less marked degree. The samples from the edge are rather poor. At St. 1, two equal hauls 300—0 metres exhibited an interesting difference in volume. One sample measured 10 cc., while the other, taken 1—2 hours later, amounted to 28 cc.

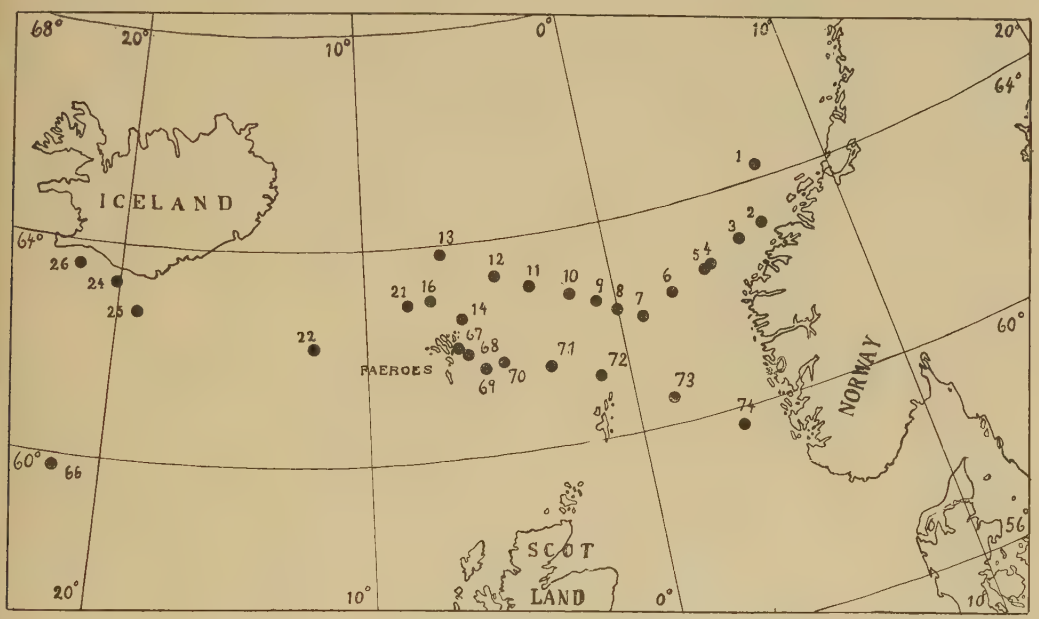

Fig. 4.

Moving farther to the south-west, into deeper water, towards Tampen, the samples become far richer in *Cal. fin.* Station 4, which lies at the mouth of the Norwegian Channel, has a haul from 600—300 m. with 81 % of *Cal. fin.* The volume of this sample was 87 cc. In this sample (taken on the $^{10}/_{7}$) we have, besides 57 % of St. V, no less than 24 % of St. IV. These two stages are probably derived from the principal spawning in the spring. Gran (1902), Damas (1905), Paulsen (1906), Damas and Koefoed (1908—09), With (1915) and others are agreed that the principal spawning season for *Cal. fin.* lies in the spring or early summer. With (1915 p. 30) says that the term spring in this case is only correct "if the spring is defined as the period at which the waters reach a certain temperature and salinity, and which varies according to the latitude from March (February?) to August (East Greenland)". Paulsen (1906 p. 19) says: "the spring is perhaps not the only repro-

ductive period of *Calanus finmarchicus*, for the reason that we find the adults of both sexes at other times of the year almost everywhere where fishing has been carried out in deep waters". The nauplii and the small copepodites at St. I, taken $^9/_7$, are from the smaller spawnings which take place in the course of the summer. At a depth from 600—300 at St. 4 we could expect to find a quantity of *Cal. fin.* The temperature in the water layers near the edge, which are rich in nourishment, is between 3.31—6.70. The adjacent Station 5 is also rich in *Cal. fin.* There are a fairly large number of specimens in the upper 50 m., in the rich plankton layers. In the upper strata at Stations 4, 5 and 6, we found a quantity of nauplii, which appeared to be *Cal. fin.* Copepodites below St. IV were not found, so that the nauplii must in this case originate from another spawning than the larger copepodites. St. 7—13 give a rectilinear section through the southern portion of the Norwegian Sea. At St. 7, four hauls were made. Of these, 3 were poor in *Cal. fin.* one haul from 300—0 m. is very rich. In a volume amounting to 81 cc. it yielded 81 % of this species. The three other hauls were from 350—250, 200—100 and 50—0 m. respectively. There is thus a great assemblage of *Cal. fin.* outside these three hauls. This shows that *Cal. fin.* may be highly restricted in its vertical or horizontal distribution.

St. 8 has an even quantity of *Cal. fin.* in all hauls. In the sample from 800—500, where the volume was 26.5 cc., we have 49 % of this species, 29 % St. IV and 20 % St. V. The temperature in these water layers varies from — 0°.90 to — 0°.56. Station 9, which lies midway out in the Gulf Stream, is poor. Station 10 yielded almost exclusively *Cal. fin.* in the upper 50 m. The sample from 800—500 amounted only to 0.5 cc. volume. This is remarkably little in comparison with the analogous samples from Stations 4 and 8. It seems likely that the abundance of nourishment on the edge at St. 4 and 8 may account for the greater quantity. The poverty of the deeper layers at St. 10 can hardly be due to diurnal vertical migrations up to higher levels. From the results of previous investigations, *Cal. fin.* should be down in deep water at 11 a.m., when this sample was taken. Stations 11, 12 and 13 are much alike. The hauls from 50—0 are rich, but. *Cal. fin.* does not amount to any very high percentage. Stages IV and V predominate, the former rather more frequent than the latter. Taking the entire section as a whole (see Fig. 5) we see that the quantity of plankton is rather unevenly distributed.

We find a maximum along the edge. The maximum follows the edge fairly closely. Here on the edge we find a few copepodites at the surface. At the western stations, there is a maximum discernible nearer the surface. This maximum continues over towards Tampen. It approaches nearer and nearer to the surface, and disappears at the edge.

At St. 7—10, the temperature in the upper 50 m. is $> 7°.70$. At St. 11—13, the lowest temperature at 50—0 is 3°.48—3°.76. Stations 7—10 lie in the Gulf Stream water. The salinity is > 35.2 ‰. Stations 11—13 show salinity < 35.0 ‰,

Owing to the hydrographical conditions, then, we have here two separate areas. In regard to quantitative distribution, another element has also to be reckoned with. As already mentioned, there are currents near the edge which render these waters close to the edge rich in nourishment and thus also in plankton. In the Gulf Stream water itself there is but little plankton. The transition layers leading to the colder water below are also poor. The is no rich planktonic "false bottom" here discernible (cf. GRAN 1902 p. 122).

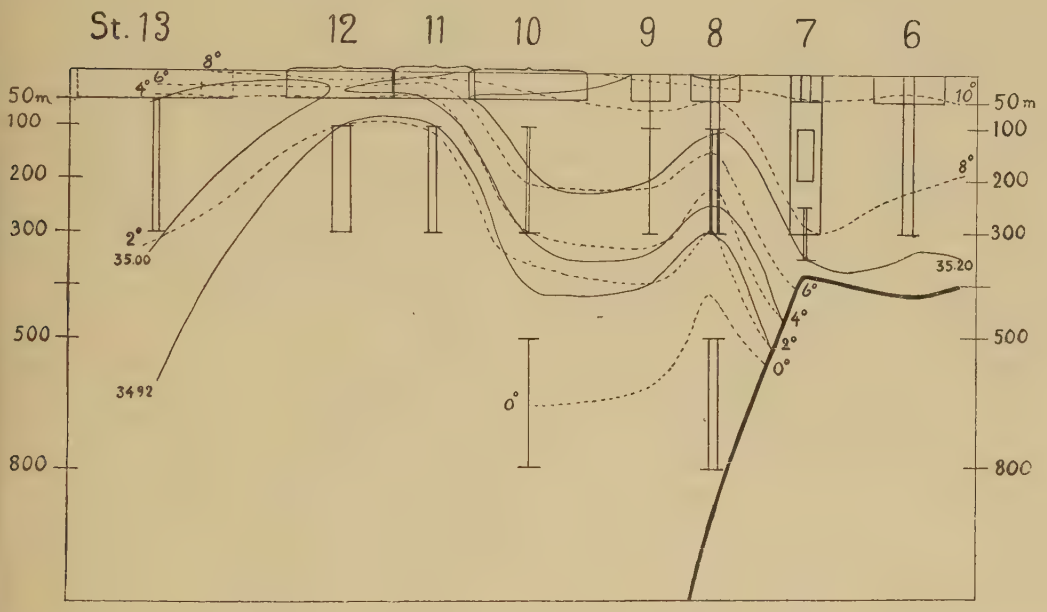

Fig. 5. Section, Stations 7—13, showing volume of plankton. Based on Dr. MARTENS' Hydrographical Section.

Stations 14, 16, 21 lie on the edge of the Færoe Bank. We find here a marked difference from the stations just mentioned. Those between the Færoes and Tampen yielded almost exclusively stages IV—V, whereas here, just as at Station 1, we find all stages represented. The sample from 50—0 at Station 14, measuring 77 cc., contained 66 % of *Cal. fin.*, nauplii excluded.

Station 22, which lies between the Færoes and Iceland, yielded but few *Cal. fin.*; an exception is formed by the samples from 800—500, which contained comparatively many. Stage V was found to the amount of 50 %, the volume of the sample being 25 cc. We have here, perhaps, a case analogous to that of the rich sample from 800—500 at Station 8. The wealth of plankton at Station 8 was presumably due to the fact that the position, in deep water, was near the edge. We find the same thing in the case of Station 22. Just to the north of the station

lies the Færoe-Iceland ridge. At Station 23, which lies out in the Atlantic, a good way from the edge, the sample from 800—500 measured only 6 cc. In the upper 100 m. we found, besides St. V, also many of St. VI♀. At 50—0 there were 86 % *Cal. fin.*, of which 2 IV, 39 V, 45 VI♀. It should here be noted however, that the percentage of *Cal. fin.* is probably somewhat too high in proportion to the small copepods. It was difficult to count this sample owing to the amount of slime from Medusæ. The volume of the copepods was abt. 11 cc.

Off the coast of Iceland, on the edge and on the bank, we find many nauplii and small copepodites. The youngest specimens are found more especially in the samples from 50—0 m. At 100—50 we find some few adult ♀♀ and ♂♂. At 180—100 there were some VI♂ but no VI♀.

We find here the phenomenon noted by O. Paulsen (1906 p. 14), that the adult ♂♂ seem to live somewhat deeper down than the adult ♀♀. Adult specimens at this station were however, but few. O. Paulsen found in June quantities of *Cal. fin.* St. IV—VI, especially to the south of Iceland; he mentions also the finding of nauplii and small copepodites. In August he observed some slight spawning. The samples from the "Michael Sars" agree well with Paulsen's observations. Our samples were taken on the 20—21 July, and resemble mostly Paulsen's samples from August.

Stations 27—30 constitute a section from Iceland over towards the southern extremity of Greenland. From a hydrographical point of view, the stations are remarkably uniform. The fauna is of the Atlantic type. Volume of samples small. Percentage of *Cal. fin.* varies greatly. At St. 27 and 28 we find, at 100—50 m. 46 % and 20 % of adult ♀♀. These are found almost exclusively at this depth. At 300—100 m. we have, at Station 27, 7 % adult ♂♂. Here again we have the peculiarity that the ♂♂ are met with rather lower down than the ♀♀. At St. 27—29 we have *Cal. fin.* fairly evenly distributed down to 1500—800 m. A few small copepodites are found scattered about, but generally speaking, it is St. V which is found.

It is not until nearing Greenland, at St. 30, that we find many young specimens. Here we have 7 % St. 1 of *Cal. fin.* together with 16 nauplii which are pretty certainly *Cal. fin.* Station 31, which lies a little west of St. 30, has the cold polar current at the surface. The yield of copepods was very small in point of volume, but might well contain numerous specimens of *Cal. fin.*, when we consider that 35 % of the copepods are nauplii which can with a high degree of probability be referred to this species. In addition to the nauplii, we found 4 I, 1 II and 1 III. We must thus hav been in or near water masses where spawning was taking place or had recently occurred.

Unfortunately, we have only samples from 50—0 at St. 30—31, and cannot therefore determine whether there are adult ♂♂ and ♀♀ in deeper water. The temperature at 50—0 metres varies from 3°.72 to 7°.74. This agrees well with

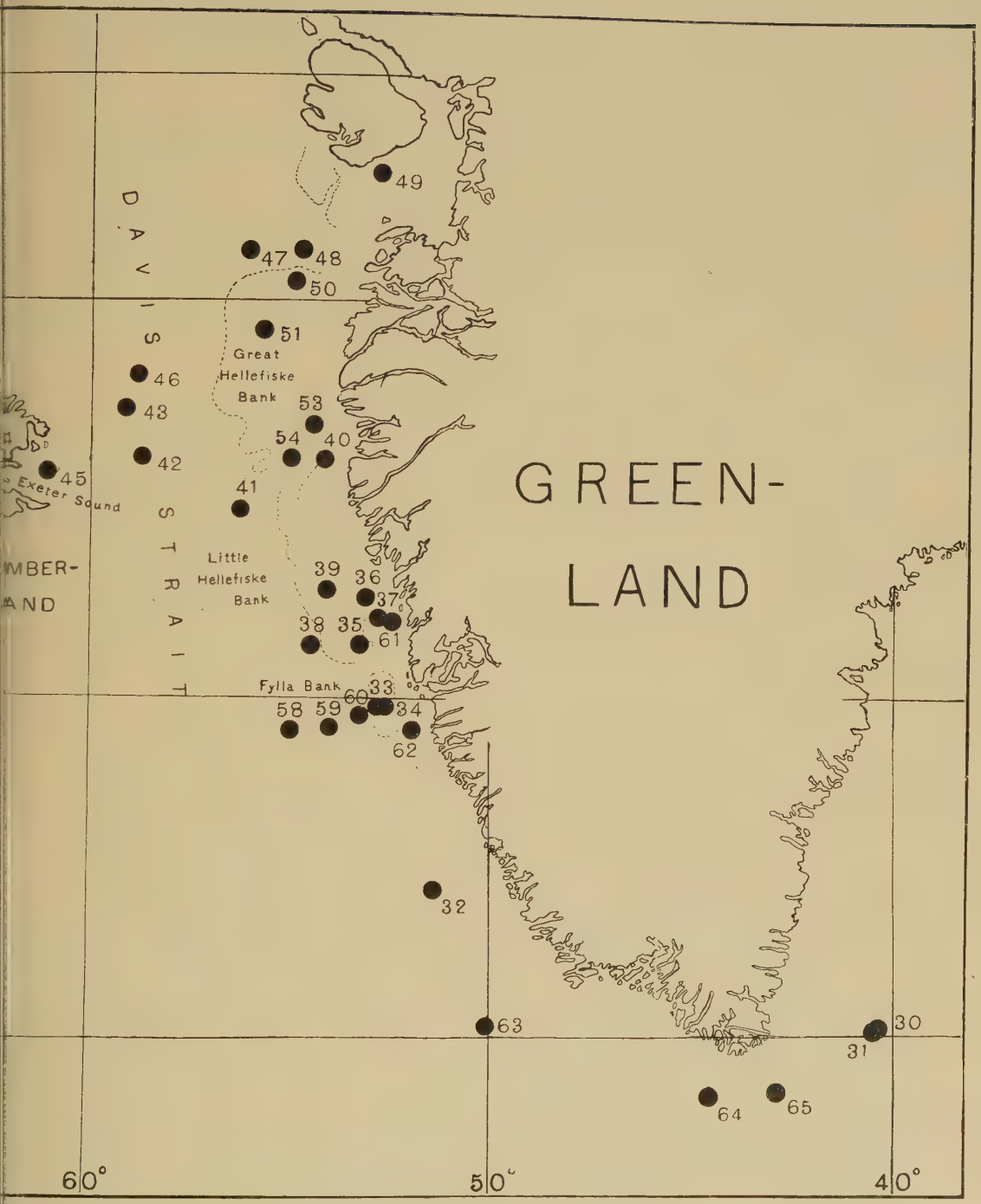

Fig. 6. Position of the Greenland Stations.

Damas' records (1905) of spawning temperature in the Norwegian Sea, which he gives as between 4°—6°. Salinity varies from 29.01 ‰ to 34.94 ‰. The cold water lies sharply defined from 25—0.

We will take the Greenland stations according to their geographical position. St. 64 lies due south of Cape Farewell. It yielded a few *Cal. fin.* in the upper 100 m., St. IV predominating.

The sample from 300—100 is rich. We have here the usual massing of St. V. Stations 63 and 32 lie farther out from the coast. In the upper 100 m. the temperature is $> 5°$. The upper 50 m. at both stations are rich in St. V. The depth interval from 100—50 is much poorer, but we find here most VI♀♀. We have thus

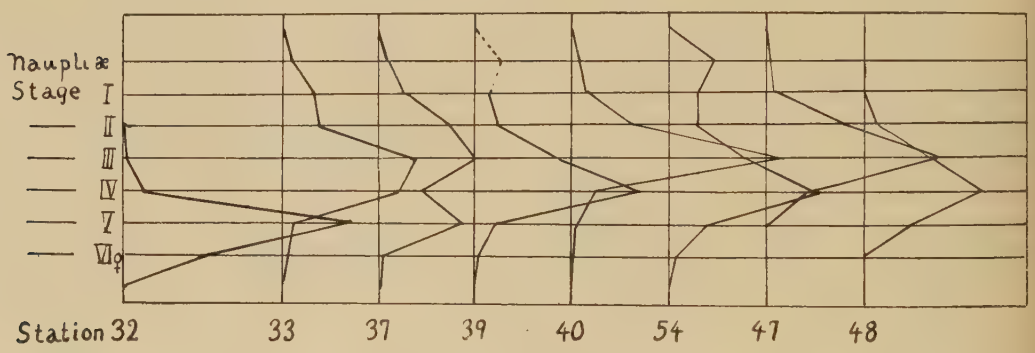

Fig. 7. Distribution of the various stages of *Calanus finmarchicus* at 100—0 m., at stations on the West Coast of Greenland.

at this station, two stages, V♀ and VI♀, distinctly separate. Moving farther north up on to the banks, we find almost exclusively juniores. On the bank stations, I counted out about 50 *Cal. fin.* from each sample, in order to form an idea as to the distribution in point of stages; the result will be seen from Table C.

Figure 7 gives all the counts taken together.

In the table, the stations are noted according to their position in degrees of latitude. It will be seen that nauplii and all copepodite stages occur. Stages II—IV predominate in the upper 50 m. Stages III—IV from 100—50. Hydrographical observations show a layer of very cold water above the banks. The hauls in the upper series of the table (50—0, 15—0) were all taken in the warmer surface layer. The lowest series (100—5, 60—20) were taken from the colder water, with temperature $< 2°$. Previous investigations have shown that there is a current running northward along the coast (Wandel 1893 and Knudsen 1898 p. 131). A current profil of Davis Strait of Martens also shows that there is a slight current running northward along the west coast of Greenland. According to the profile

Table C. Distribution of the various stages of development at stations on the coast of Greenland.

Station	32	33	37	39	40	54	47	48
Depth interval of haul	50—0 m.	15—0 m.	50—0 m.	50—0 m.	50—0 m.	50—0 m.	50—0 m.	50—0 m.
Temp. in the surface	6.55°	6.10°	4.55°	4.31°	5.16°	5.34°	5.14°	5.30°
— nearest bottom	5.66°	abt. 6°	2.31°	1.30°	3.65°	1.00°	1.27°	2.08°
Nauplii	..	3	2	5	2	13	1	..
Stage I	..	10	7	3	3	9	2	..
— II	..	11	19	4	2	9	15	4
— III	1	15	19	13	13	11	29	16
— IV	4	10	2	24	1	9	4	25
— V	67	2	1	2	..	..	..	5
— VI ♀	..	..	..	..	..	..	..	..
— VI ♂	..	..	..	..	..	..	..	..
Depth interval of haul	100—50 m.	60°—20 m.	100—50 m.	90—50 m.	100—50 m.	100—50 m.	100—50 m.	100—50 m.
Temp. nearest bottom	5.37°	1.41°	1.56°	1.20°	0.97°	1.35°	0.71°	1.23°
— — surface	5.66°	abt. 2—3°	2.31°	1.30°	3.65°	1.00°	1.27°	2.08°
Nauplii	..	..	..	..	..	..	..	..
Stage I	..	..	..	1	1	..	..	..
— II	..	1	2	3	17	..	9	.
— III	..	27	11	13	52	13	24	4
— IV	2	27	11	27	6	36	8	11
— V	4	1	25	5	1	11	..	9
— VI ♀	26	..	1	1	..	2	..	..
— VI ♂	..	..	..	..	..	..	..	..

in question, the velocity of the current above the banks is greatest at the surface. From the hydrographical sections we see that the cold water above the banks increases in quantity to the northward. We may thus suppose that there is a wedge of cold water extending southward over the banks.

We have seen from the table that St. III—IV were mostly found in the cold water layer above the banks. The hauls from the warmer surface water also yielded considerable numbers of smaller stages, from nauplii upwards. Such a distribution of the stages can hardly be supposed to be due to simple scattering of the organisms with the current. On glancing at the table for total vertical distribution of the various stages of *Cal. fin.* (Fig. 9) we find that the nauplii and stages I—II occur almost exclusively at 50—0 m. Stages III—IV are found in somewhat deeper layers. From the vertical distribution of the stages, it seems as if *Cal. fin.*

at stages II—III, is already commencing its migration down to deeper water (p. 23). The finding of stages III—IV in the cold water layers above the banks must presumably be due to migration on the part of the organisms as soon as they have reached a sufficiently advanced stage of development. Those in the cold water on the bottom and along the edge of the banks west of Greenland will, on the one hand, be slower in their northward drifting than those at the surface where the current is somewhat stronger. We thus find another and more complicated distribution of the stages relative to the spawning grounds than that stated by DAMAS and PAULSEN for the waters they have investigated: DAMAS states that the size of the stage increases with the distance from the spawning grounds. In the present case, where the later stages move down into deeper water layers, they can, as we see, be retained there, and not disperse, so that we have a steady increase (in numbers) of the later stages in the spawning grounds.

On the other hand, the movements of the organisms down into colder water masses will impede their further development. For according to GRAN (1902 p. 64), development proceeds more slowly in cold water than in warm. Given a steady spawning throughout a lengthy period, a descent into such cold water as we find deep down at these stations would probably lead to a considerable retardation of development, so that stages III and IV would also be numerous.

In the waters west of Greenland there can surely not have been any definitely limited spawning area. The scattered occurrences of adult ♀♀ suggest that spawning takes place in many different places at any rate as late as August. At Station 54, no dispersal of the stages has taken place. All the stages are found in considerable numbers. Station 54 lies between the south-going current on the west and the north-going current to the east. The two most northerly stations have practically speaking no stages below II—IV. It is possible that these may have drifted thither from the south. Station 40 yielded an overwhelming majority of Stage III. Station 54 which lies in the same latitude, but a little farther west, has more of Stage IV. Station 58 was taken 8 days later. It is possible that a number of the specimens in Stage III from Station 40 had entered upon Stage IV. The great quantity of one particular smaller stage found at Station 40 seems to suggest that spawning had taken place to some considerable extent within relatively short time.

The stations on the edge outside the bank are not particularly rich. Outside the Fylla Bank and Little Hellefiske Bank we find Stage V in somewhat deeper water. The percentage of Stage V decreases to the northward. Up on the Great Hellefiske Bank there were relatively few of Stage V.

The samples from 50—0 in the fresher coastal water yielded but a small volume of copepods. Samples from 50—0 farther out from shore, on the other hand, were very rich. Stations 60, 46, 47, 48 yielded relatively large volumes, but the percentage of *Cal. fin.* was very small, especially at the stations farthest north. It is not easy to discern any definite distribution of *Cal. fin.* according to hydro-

graphical conditions. We do not find any rich water layers at the point of transition between the cold polar water and the subjacent warmer water from the Atlantic. Station 41, just off the banks, yielded only 6.8 cc. in the sample from 300—100 m. with 16 % *Cal. fin.* The temperature varies from — 0°.51 at 100 m. to 3°.92 at 300. Taking all stations together, we get the distinct impression that the percentage of *Cal. fin.* decreases and disappears as we move towards the north-west into the cold polar water. Up in the depths of Exeter Sound and Disko Bay we find a number of *Cal. fin.* Stage V.

The West Greenland waters investigated by the "Michael Sars" Expedition have already been subjected to thorough investigation by the Danish Ingolf Expedition. With (1915 p. 20) says of his counts of *Cal. fin.* stages from the west coast of Greenland: "It is impossible to draw any conclusions except that all stages occur fairly frequently in the month of July and June". He further states: "In the month of July it is safe to conclude that propagating takes place at that date". Two of the samples investigated by him from August and September contained chiefly stage IV. Jespersen (1923) found many adult ♀♀ in Disco Bay in July.

In conjunction with the results of the "Ingolf" Expedition, those of the "Michael Sars" throw a good deal of light on the distribution of *Cal. fin.* in the waters west of Greenland.

Since the majority of the specimens are Stage III—IV, we must take it that the principal spawning occurred earlier in the summer. The mean temperature of the surface water off the west coast of Greenland, from Davis Strait southward is, according to Ryder (1917 Charts 5—7) for May, 0°— —1°, June abt. 2°, July abt. 4°. The few VI ♀♀ and nauplii found in August suggest that there is no great amount of spawning taking place at this season. As we lack stations along the coast to the south-west, it is difficult to determine the limit for spawning to the southward. Station 64, south of Cape Farewell had, however, a number of juniores.

Those individuals which are spawned on the banks drift northward and westward with the current. They find the water in which they move steadily growing colder, partly because they are drifting north and west, and partly also because they move down into the cold water on the bottom and along the edge of the banks. They develope but slowly in the cold water. This state of things prevails in August. Autumn and winter come, and still further retard development. According to Gran, the organisms may now be supposed to go through their development slowly in the course of the winter. Gran states (1902 p. 61): "Wenn diese Erklärung rigtig sein sollte, müssten die zahlreichen jüngeren *Calanus* die im Herbst noch in dem Oberflächenschichten noch schwimmen, mit dem Eintreten des Winters die Tiefe suchen, um dort langsam ihre Entwicklung zu vollenden". The slow development in cold water which the organisms have undergone right from the smaller copepodite stages should, according to Gran's view, lead to their turning out larger than usual. From the measurements taken of Stage V in Greenland waters (see

p. 6) it will be seen that we have here two distinct size groups of *Cal. fin.* From Fig. 2 it will be seen that the southern stations yielded specimens of the smallest size, while in the north, in the colder water, we find the larger individuals. Up in the cold water of Exeter Sound we measured 47 large and 3 small specimens. Near the Hellefiske Banks there are about equal numbers of each size group. South of the banks, we find only small specimens.

Stage VI♀, of which few are found in August, is met with most at the southern stations. All the specimens measured were small. Farther to the north, a few larger ones were found.

How can it be that there exist two so distinctly separate size groups of *Cal. fin.*?

Considering temperature alone, we should expect to find a regular increase in the length as we move northward into colder water. That the difference should be due to a general difference of size between the two sexes is out of the question, as some of the samples contain practically speaking none but the one size. Moreover, the difference is considerably greater than that which exists between ♀ and ♂.

The two large specimens of Stage V which we find at the northern stations must, from what we know already, have developed slowly in cold water. They doubtless belong to Greenland waters. From With's investigations on the "Ingolf" Expedition and the present investigations of the "Michael Sars" in 1924, we find that a spawning of great extent had taken place west of Greenland earlier in the summer. In August, the majority of the specimens from this spawning were at Stages III—IV.

It is very hard to suppose that the large specimens of Stage V which, from their size, should have taken longer over their development, should be the product of this early summer spawning. The question then is whether they were spawned in the course of the winter. Unfortunately, very little informations is available as to the spawning of *Cal. fin.* in winter. Nordgaard and E. Jørgensen (1905) found a high percentage of VI♀ in the deeper waters of the Norwegian fjords during winter. As far as we know, it seems as if spawning only took place here and there during winter, the principal season being in spring or early summer. The comparatively large number of the larger size group of *Cal. fin.* suggests that these individuals originate from a definite spawning of great extent.

From this, then, we may suppose that the large specimens of Stage V were spawned west of Greenland during the previous summer. The large specimens of Stage V are thus probably over a year old.

Together with the large specimens we find specimens of the smallest size group. These have their principal area of distribution to the southward. The small specimens of Stage V must have developed in warmer water, and taken comparatively little time over the process.

The majority of the small specimens doubtless originate from this spring

or early summer spawning. The larger numbers of small Stage V in the south may fairly certainly be regarded as the product of this spring or early summer spawning. Paulsen (1906) mentions that there are masses of St. V south of Iceland in July—August. These were spawned in the spring. It is possible that some of the small forms farther north may be from the previous year's spawning. They may be specimens which have moved up from the relatively warm Atlantic water deeper down. For we find a number of small St. VI♀. We can hardly suppose that those in the north should originate from the current year's spawning. The majority of the small VI♀ are found, as mentioned, to the south. Here, there is a possibility that even St. VI♀ might be from the spawning of the same spring. Specimens which have attained Stage V and are carried by the current to other regions, might arrive at maturity and spawn even when only abt. 4 months old. Lebour (1916 p. 9) shows that the development of *Cal. fin.* can proceed fairly rapidly: "Stage V was taken from the jar having taken certainly less than two months to grow from egg to this stage". It looks as if *Cal. fin.* remained at Stage V until conditions prove favourable for spawning. They then pass over into the relatively brief stage of maturity (cf. Damas and Koefoed 1908—09 p. 385). The question as to age of the small specimens cannot be determined with certainty from the material available, which only covers a period of three weeks.

From the few measurements made with St. IV we find that there were not two distinct size groups. The size interval was very great. As we do not find any separation into two size groups, we must conclude that the specimens are not derived from two distinct spawnings far removed in point of time. It is likely that the specimens of Stage IV originate from the spawning of the early summer in that year in Greenland waters. The great variation in length must be due to mingling of specimens from water layers of different temperature.

Summing up the results, then, we should, in the Greenland waters, have at least 2 groups of *Cal. fin.* One of large specimens spawned in Greenland waters during the previous summer, and another of small specimens spawned farther south the same spring and carried northward with the current. It is also possible, as already mentioned, that some few of the small ones may be from the previous year. Gran (1902 p. 64) holds that some specimens in the colder part of the Norwegian Sea should be over a year old. He says: "Man müsste dann annehmen dass *Calanus finmarchicus* im nordwestlichen Theil des Gebietes 2 Jahre für seine volle Entwicklung brauchte". That *Cal. fin.* should take more or less than a year to complete its development must be regarded as exceptional. Damas and Koefoed observe in this connection: "Un point capitale paraît établi d'une manière certaine; *C. finmarchicus* est une forme annuelle". The annual life cycle is the normal for *Cal. fin.* but the present material from the "Michael Sars" expedition to Greenland 1924 suggests that external circumstances, such as transportation by currents to water

layers of different hydrographical conditions may prolong (and perhaps also shorten) the annual life cycle.

The Atlantic Station 66 on the homeward voyage from Greenland was extremely poor in *Cal. fin.* In the deepest hauls we find some few of Stages IV and V. Stations 67—69 are extremely poor in *Cal. fin.* Station 69 yielded in the samples from 100—50 and 50—0, less than 100 copepods. The saturation percentage of

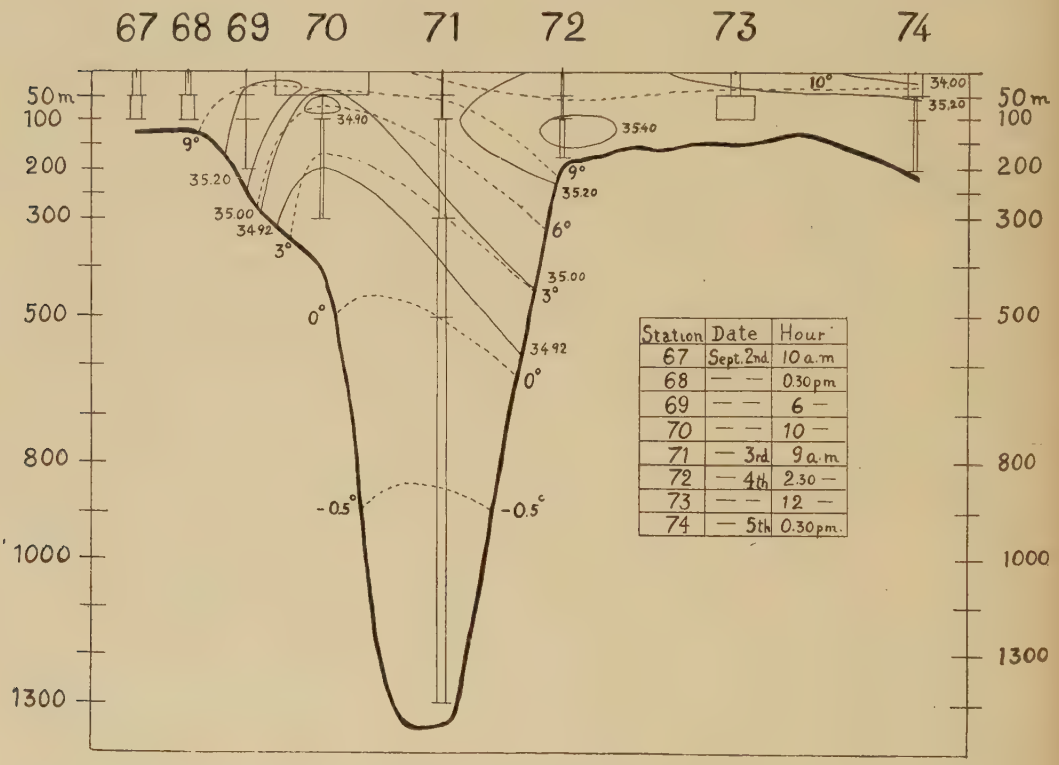

Fig. 8. Section, Stations 67—74, showing volume of plankton. Based on Dr. Martens' Hydrographical Section.

oxygen is small. At Station 67, the maximum is 96 %; Station 69 has 103 % at the surface. Station 70 shows an increase in the percentage. We find here masses of *Cal. fin.* Stage V. They keep to the upper 50 m. The sample from 50—0 measured 40.5 cc. and contained 97 % of *Cal. fin.* The deeper layers are poor. This is probably due to the fact that the organisms have moved up towards the surface. The station was taken at 10 p.m. According to Esterly (1912) and Russel (1925) it is precisely at the surface that we should expect to find *Cal. fin.* at that time of the twentyfour hours. There is a very great difference between the quantities of *Cal. fin.* at Stations 69 and 70. Both stations lie on the edge of the Færoe Bank.

The cause of the great difference in quantity of *Cal. fin.* must be sought in the hydrographical conditions. At Station 69, we have a branch of the Gulf Stream water, which is poor. At Station 70, the cold, and less salt water of the Norwegian Sea is forced up towards the surface, and stands like a wall against the Gulf Stream in on the edge. The Gulf Stream water is poor, whereas the adjacent colder water masses are rich. At Station 71, the cold and fresh water layers do not reach so high up. The upper 100 m. have very few *Cal. fin.* Not till we get below this depth do we find a fair quantity in the hauls, right down to 1300—500 m. At 300—100 we find predominantly Stage V, with some few Stage VI ♀. At 500—300 there are, besides Stage V, some few Stage IV, no Stage VI. At 1300—500 we get 20 % of IV and 24 % of V. We see then, that the stages decrease with increasing depth and falling temperature. In the upper 100 m. there are a few small stages, but the volume is so small that they cannot be compared with the considerably richer samples from deeper down. That the rich layers at this station lie below 100 m. may well be due to diurnal vertical migrations. Station 70 was taken at 10 p.m. whereas Station 71 was taken at 9 a.m. At Station 72 we enter the Gulf Stream. These water layers here are almost as poor as the corresponding ones at Station 69. Both volume and percentage of *Cal. fin.* are small. At Station 73 there are small copepodites of *Cal. fin.* at 100—50 m. The sample from 100—50 is considerably richer than that from 50—0. This may perhaps be largely due to a downward movement of the copepods in the middle of the day. But the smallest stages are, judging from the curve for vertical distribution (Fig. 9) apparently incapable of undertaking any diurnal vertical migration. The figure shows that their distribution is almost entirely restricted to the upper 50 m. We may take it that the small stages have their natural environment at 100—50 m.

At St. 74, which was taken in the middle of the night, we find a number of Stage V at 50—0. At 200—100 and 100—50 there are few *Cal. fin.* Stage IV predominates. The station was taken at 0.30 a.m. It is likely that Stage V here moved up to the surface layers, but from the distribution of Stage IV it would seem as if this stage does not make such pronounced diurnal vertical migrations as Stage V. The finding of the small copepodites in deeper water at Station 73 and 74 might perhaps be due to excessive warmth of the surface water: it is possible that the small stages require temperatures approaching the spawning temperature.

We will now endeavour to compare the two sections, taken at an interval of nearly two months.

In the northern section, in July, we found that Stage IV predominated at the western stations. To the east, on the edge, in the Gulf Stream water, Stage V predominates. In the cold water deeper down where the temperature lies below 1°, we find a fairly constant ratio between Stages IV and V, approximately as 4 : 3.

In the southern section, at the beginning of September, Stage V is found

to predominate at all stations. The sample from the cold water below 500 m. yielded 20 % of Stage IV and 24 % of Stage V.

As already mentioned, I supposed that the specimens of Stage IV from the western stations originated from the main spawning season in the spring. The occurrence of Stage V in the southern section suggests that those specimens which were at Stage IV in July have all attained Stage V.

The few deep hauls from the colder water masses in the southern section do not seem to indicate any marked development from Stage IV to Stage V. Stage V is, it is true, a little more numerous than Stage IV, but the one haul is not sufficient to afford a general view of the position. There seems to be a certain stagnation in the development in the deeper cold water layers. The specimens of Stage V were of normal length (see Fig. 3). This suggests that they must have lived, as younger copepodites, in warmer water layers. From this we may conclude that the specimens in question must have been spawned in the spring of this year. They must have moved down into deep water at about Stage IV. These Stages IV and V, which seem to occur in fair quantity in deep water along the edge towards the Norwegian Sea, are probably those which attain maturity in the spring and move up in great numbers to spawn. We have here forerunners of the copepodite stages which according to GRAN should have moved down into deep water some way on in autumn (see p. 17).

Vertical Distribution of *Calanus Finmarchicus*.

It has already been pointed out several times that the small specimens of *Cal. fin.* keep to the surface. PAULSEN (1906 p. 14) mentions this fact, and further points out that Stage VI ♂ will as a rule be found somewhat deeper down than VI ♀. The larger copepodites are met with at all depths. ESTERLY (1912) and RUSSELL (1925) have demonstrated the existence of vertical diurnal migrations on the part of *Cal. fin.* They have not investigated each stage separately, but took all together. WITH (1915 p. 28) mentions that the difference in numbers of specimens in hauls, especially from East Greenland "indicates that all stages inhabit the surface layers in the night in some regions and some seasons, in which only the youngest copepodites or the larves are frequent during the day". The stations of the "Michael Sars" Expedition lie so far apart that we cannot observe vertical migrations at approximately the same place. In Greenland waters, but few of the stations were taken at night. Stations 46 and 54, which were taken at 11.30 p.m. and 9.0 p.m. had a few *Calanus* at 50—0. It must be borne in mind that the difference between day and night is not very marked at these northernmost stations. Stations 70, 71, 73 and 74 appear to indicate diurnal vertical migrations. Here, as already mentioned, we find *Cal. fin.* at the surface in the night, and deep down during the day. At Station 74 it seemed as if Stage V especially, and Stage IV

to a lesser degree, moved up towards the surface during the night. Unfortunately, the material is not sufficiently extensive to afford any solution of the question as to migrations of the different stages.

On the cruise of the "Michael Sars" the vertical hauls were made as far as possible within certain definite depths. In this way it was possible to make direct comparison between the different stations. 54 vertical hauls were made between 50—0, 38 from 100—50, 37 from 300—100, 12 from 500—300, 10 from 800—500, and 3 from 1500—800. The number of hauls also includes those taken within the range of depth indicated, but covering less vertical extent. Fig. 9 shows all the counts from the ordinary hauls taken together. The sum of the different stages from one depth interval is divided by the number of hauls. This gives the mean percentage for the depth in question. In Fig. 9, the abscissa indicates the percentage, the ordinate the depth. The curves show that Stage V occurs in far greater numbers than the other stages. This is mainly due to the time of year. At the close of the summer we have masses of organisms which were spawned in the spring and have now attained Stage V. The greatest percentage of *Cal. fin.* is found at 100—50 m. We will not proceed to consider the different stages.

The nauplii are found almost exclusively at 50—0 m. The percentage of nauplii is uncertain, as the species at this stage are easily confused. Stage I follows the nauplii in point of distribution. Stage II runs somewhat deeper. We find about equal quantities at 50—0 and 100—50 m. Farther down, this stage is hardly found at all. Stage III has its maximal distribution at 100—50; few are found in deeper water. Stage IV differs from the foregoing stages; it is found in numbers at all depths downwards. The minimum shown by the curve at 500—300 is largely due to the fact that hauls were hardly ever made at this depth in the Norwegian Sea. The maximum at 800—500 is due especially to the rich hauls made in the Norwegian Sea. Stage IV, like Stage III, is nearly twice as numerous at 100—50 as at 50—0. The relatively low percentage for 50—0 is also found for Stage V. Of this stage there were, on the average, 11.0 % at 50—0 and 25.3 % at 100—50 m. Stage V is found regularly throughout all depths. The great bulk of Stage VI was found at 100—50; we have unfortunately but little material of Stage VI ♂. They occur equally at 100—50 and 300—100. Summing up the distribution of the stages, we find that:

Nauplii and first copepodite occur almost exclusively in the upper 50 m.

Second copepodite stage almost exclusively in the upper 100 m.

The third copepodite stage keeps mainly to the upper 100 m. but may also be met with deeper down.

The fourth and fifth copepodite stages were found at all depths investigated.

The adult ♀ occur for the most part at 100—50 m., or scattered throughout all depths.

The adult ♂ are found at 300—50 m.

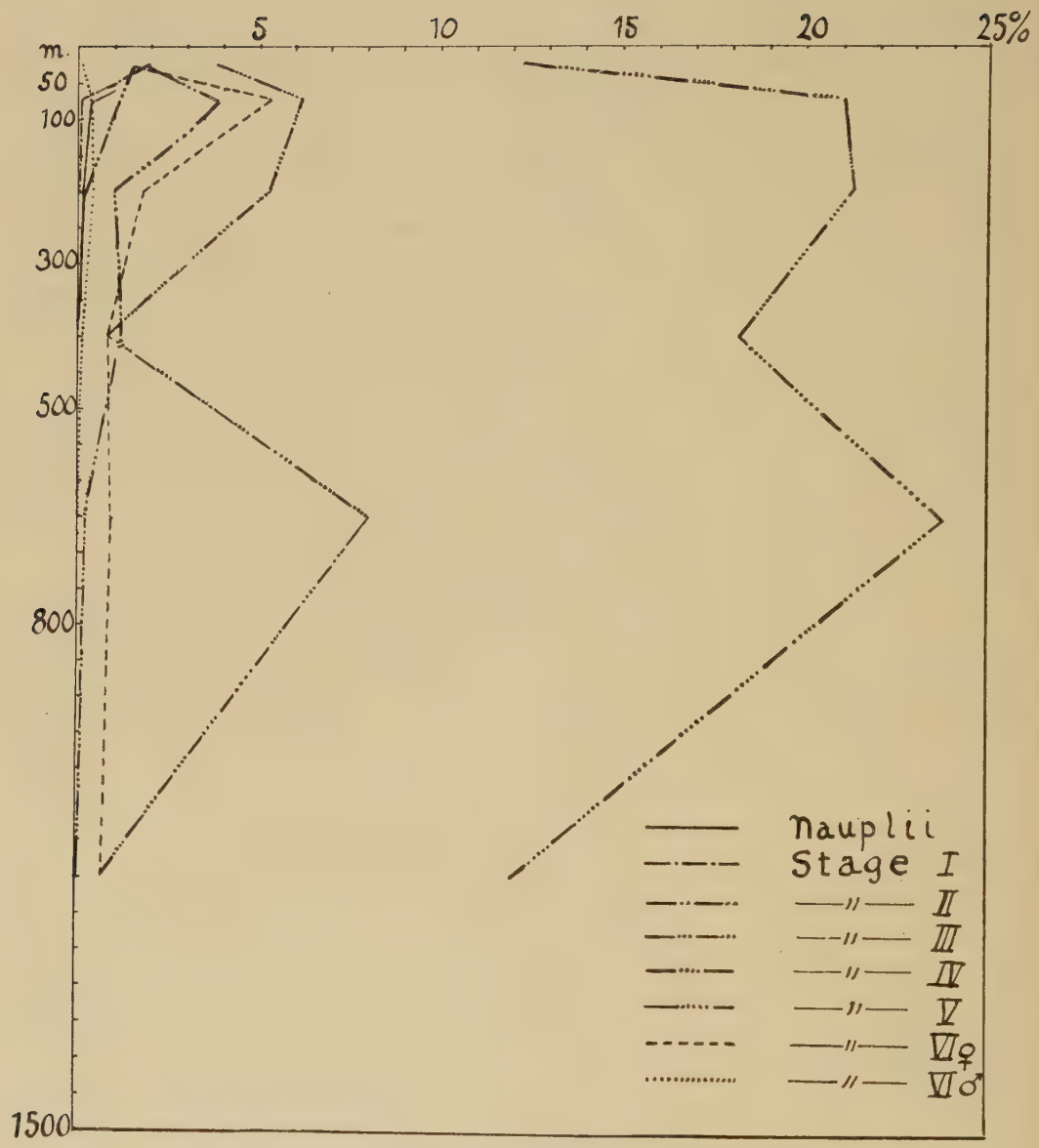

Fig. 9. Mean vertical distribution of the different stages of *Calanus finmarchicus*.

We arrive then at the result that, as previous investigations have also shown, the youngest organisms live in the surface layers, scattering throughout the various depths as they grow older.

This may be due to the fact that the larger copepodites have been so long in one water layer that this in course of time changes its position, owing to the

action of the currents, in a vertical direction. In such case, there would be no independent movement on the part of the organisms themselves. It might also be supposed that the organisms, in course of growth, acquire the capacity for vertical migration. We know, as already mentioned, that older specimens of *Cal. fin.* can make diurnal vertical migrations of considerable extent. It is possible that the copepods make vertical migrations apart from the diurnal. At what stage is the power of making vertical migrations acquired?

As we have seen from Fig. 9 the nauplii and Stages I—II are found in the upper 100 m. Stages IV—V are met with at all depths. Stage III forms a transition. This suggests the possibility that the organisms at about stage III acquire the power of vertical movement. As already mentioned however, it is possible that the vertical distribution of the older individuals may be due to the action of the currents. The duration of a stage can, where the temperature is low, be of relatively considerable extent. The problem as to vertical migrations of the individual stages could doubtless be solved by investigations in localities where current conditions are of the simplest order.

We will now proceed to consider the distribution of the stages at the separate stations. Station 54 shows distinctly how the later stages increase in numbers with increasing depth.

Table D. St. 54. $^{16}/_{8}$ 9 p. m.

Stages	150—100 m.	100—50 m.	50—0 m.
Nauplii	..	..	13 ?
St. I	..	..	9
- II	..	..	9
- III	8	13	11
- IV	21	36	9
- V	21	11	..
- VI ♀	4	2	..
- VI ♂	..	..	..
Volume of sample	7 cc.	8,5 cc.	5 cc.

This station was taken at a time when we should expect to find *Cal. fin.* assembled in the upper water layers. According to Esterly (1912) they should be found at the surface from 7—8 p.m. That the vertical migration is here so slight is probably to a great extent due to the slight difference in the intensity of light between day and night in these northerly waters. At Station 74, which was taken at midnight, we find a quantity of Stage V at 50—0. In the deeper hauls, the percentage of Stage IV is > V. It looks as if Stage V had moved up towards the surface.

Calanus Hyperboreus Krøyer.

This arctic form is as a rule, in the larger stages, IV—VI, easily distinguishable from *Calanus finmarchicus*. In these stages, we have, besides the difference in size, also the spine on the posterior thoracic segment as a distinguishing character of *Cal. hyp.* In going through the material, it was found that some few specimens of Stages IV—V of *Cal. hyp.* were very little larger than the largest specimens of *Cal. fin.* at the corresponding stage. In some few small specimens of *Cal. hyp.* the spine on the posterior thoracic segment was much reduced.

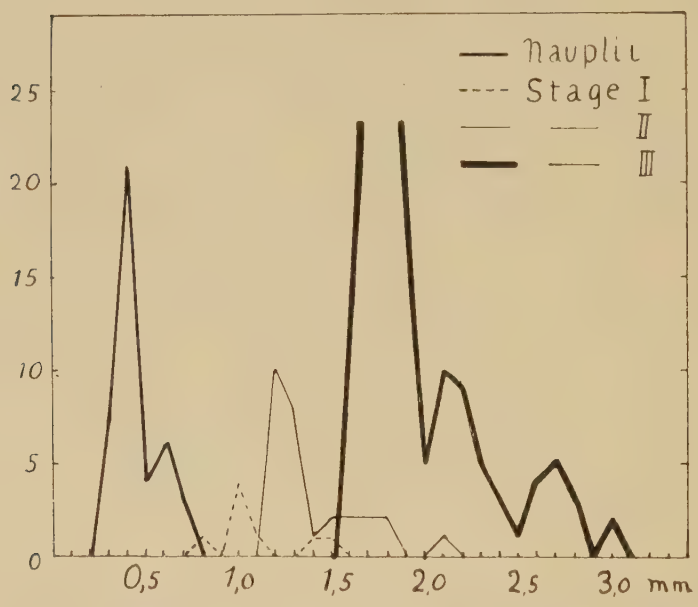

Fig. 10. Rough measurements of young stages of *Calanus* from Greenland.

In order to endeavour to separate the smaller stages of the two species, I have made some rough measurements during the countings of our material from the Greenland waters. These measurements are shown in Fig. 10. The length is taken from the front of the head to the end of the caudal fork. Among the nauplii there may very possibly be some other species as well. In the case of Stage III, the curve is not complete, owing to the fact that in many cases, I had only noted the length as less than 2 mm. We see from Fig. 10 that the two species cannot be definitely distinguished by their size. The number of specimens measured was as the ordinate shows, but small. Comparing the sizes with the data given by With (1915) it becomes very natural to take the size limit for the two species at Stage III as 2.5 mm. In the case of Stage II it is difficult to set any definite limit. According to With, the boundary should lie somewhere between 1.6 and 1.8 mm.

In regard to Stage I it is natural to regard the two specimens of 1.4 and 1.5 mm. as *Cal. hyp.*, the remainder as *Cal. fin.* In the tables, the limits for Stage II and Stage III have been fixed at 1.7 and 2.5 mm. respectively. Specimens $\leqq$ these lengths are referred to *Cal. hyp.* As the curves are not clearly divided, we cannot expect to find any definite determination of the species.

Distribution.

At the stations in the Norwegian Sea, *Cal. hyp.* was found occasionally in the deeper water layers. At the colder stations 11, 12, 13 the species is found in the sample from 300—100. At Station 22, south of the Færoe-Iceland ridge, one VI♀ was counted, from 800—500 m. The minimum temperature here was 6°.94. At Station 30, *Cal. hyp.* is found at 50—0. The temperature is fairly high, but the station lies in the vicinity of the cold polar current. At stations west of Greenland, a number of *Cal. hyp.* were found. Few specimens were taken in the upper 100 m.; the cold water layers from 300—100 inside the banks at Stations 62, 37 and 40 are relatively rich. The percentage of this large copepod is as a rule low in comparison with the small copepods, but a small number will suffice to set its mark on the plankton. The cold water masses to the north and north-west have a fair quantity of *Cal. hyp.* When considering the individual stages of *Cal. finmarchicus*, we found that Stage V was far superior to the others in point of numbers.

Among the specimens of *Cal. hyp.* investigated, Stage IV is more than twice as numerous as Stage V. Of Stage IV, 116 specimens were counted, of Stage V 54, and of Stage III 23. With (1915) states that in these waters by the end of June and beginning of July, "the Stage IV has been found in the greatest number of samples but the Stage V in the largest numbers". Jespersen (1923) also found that Stage IV was predominant in the summer.

He found few of the smaller copepodites. The relatively large number of Stage IV taken by the "Michael Sars" expedition seems to point to a more or less definite spawning of *Cal. hyp.* as suggested by Damas and Koefoed (1908—9 pag. 356).

The number of specimens investigated among the smaller stages was too small to afford any definite idea as to the vertical distribution of the different stages.

Pseudocalanus minutus Krøyer **(= elongatus = gracilis = major).**

This species is found widely distributed in the northern seas. Formerly, distinction was made between three species: *P. elongatus*, *P. graciles*, *P. major*. With (1915 p. 57—59) has made a very thorough investigation of these. He found many transition forms, between the three which had been described as distinct species. With writes: "It was impossible for me to accept more than a single species". He retains the old name as that of the type, In going through the material from the "Michael Sars" it proved impossible to distinguish any clearly separate species. Damas and Koefoed (1908—09) distinguish between several species, but mention that there is the possibility of variation of a single form.

In counting the material, I determined, at the earlier stations, only Stages V—VI of *Pseudocalanus*. The smaller copepodites were counted together with any

other copepodites of microcalanides. At the Greenland station and those on the homeward voyage, I have noted all copepodite stages of *P. m.* At the last stations, the three lowest copepodite stages have been taken together, as I did not consider it necessary to keep them apart. The smallest copepodite stages of *P. m.* are so small that they will, in many cases, probably pass through the mesh of the net. We can then expect to get different quantities according as the silk is more or less choked with phytoplankton.

Distribution.

On the bank stations off the coast of Norway, *P. m.* is fairly evenly distributed. At Station 2 we find, in the upper 25 m., 20 % of stages V—VI. At stations 4—7, close to the mouth of the Norwegian Channel, numerous St. IV of *P. m.* were found at abt. 300—300. Of the 52 % *P. m.* taken at Station 7, 350—250 m., 51 were Stage IV and 1 Stage V.

In the section from stations 7—13, the cold water masses below 500 m. contained only Stages V—VI. The warm Gulf Stream Water at 50—0, Stations 7—9, has few specimens of *P. m.* Outside the Gulf Stream water, at Stations 10—11, over 10 % of *P. m.* were counted at 50—0. The quantity increases at St. 12—13, where we have 34 % and 20 %. At Station 14 on the bank, the species was lacking. Samples from the stations between the Færoes and Iceland contained only a very few specimens of *P. m.* At Station 26, on the bank south of Reykjanes, there were 40 % at 50—0. At the Atlantic stations between Iceland and South Greenland, *P. m.* was lacking. An exception is Station 27, which yielded 10 % at 500—300 m.

In Greenland waters, we find the first noteworthy quantities of *P. m.* on the Fylla Bank. They occur in the cold water on the banks and farther in. At Station 61, we had 17 % in the fresh coastal water, where the salinity is less than 32.56 ‰.

The stations farther north are richer. Stations 41—46 had 35—67 % of *P. m.* at 50—0. The deeper water layers were poorer, but specimens of the species are met with in water layers where the temperature is below 0°. At Station 46, we had 25 % at 100—50 m., where the temperature varies from —1°.04 to —1°.23. Station 44 yielded 21 % at 100—50 m., temp. —1°.25 — —1°.53. At this cold station, many small copepodites were also found. In Disko Bay, at Station 49, *P. m.* was found in great numbers, right down to the deepest hauls. The uppermost haul was relatively poor. The sample from 750—500, with a volume of 27 cc., contained 32 % of this species.

According to the "Michael Sars" material from Greenland, *P. m.* occurs in the cold water to the north and west; also in the cold water close in to shore. In the Atlantic, farther south, it is not found. All copepodite stages were taken. Whenever smaller copepodite stages were found, there were never any large quantities of one of the smaller copepodite stages, such as we found at some few stations

in the Norwegian Sea. The stages were evenly distributed. With (1915 p. 61) found no copepodite stages below IV in July. He states with regard to VI♂ (p. 63) "we are right in concluding that the seasons in which we find mature males are those of the propagation of the species". The finding of VI♂♂ at Stations 43, 46, 47, 48, 49 should, from this, suggest that spawning had taken place at the northernmost stations during the period from 9—15 August.

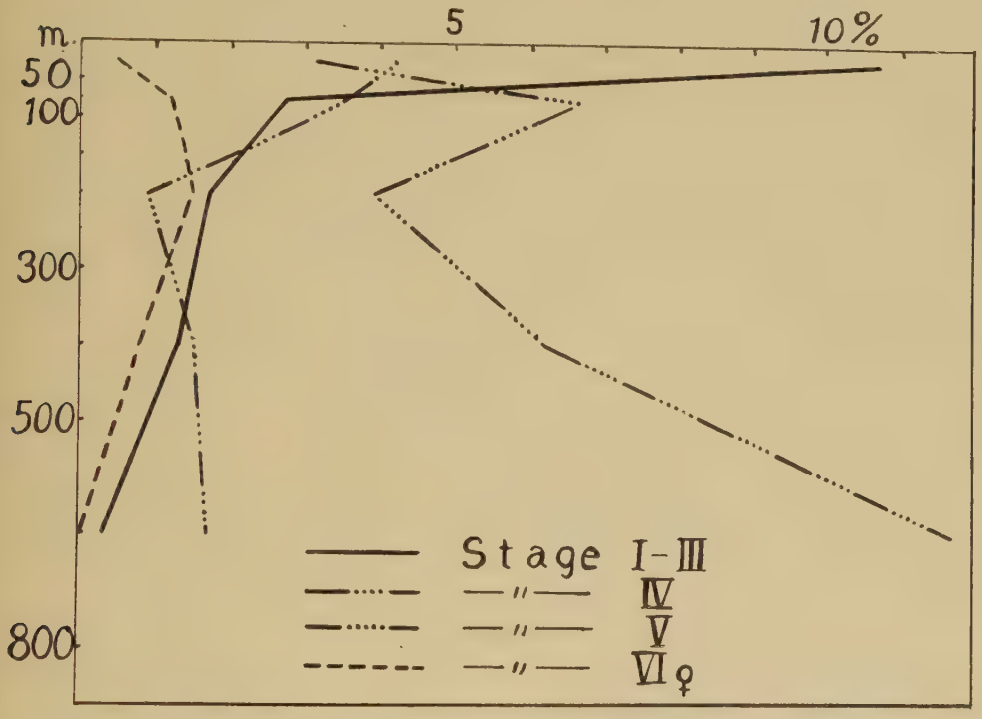

Fig. 11. Mean vertical distribution of the different stages of *Pseudocalanus minutus* at Stations 37—64, in Greenland waters.

At these most northerly stations we also find the smallest copepodite stages.

In the Færoe-Shetland section we find *P. m.* more especially on the banks. On the Færoe Bank all stages were found. Out on the edge, there were only a few specimens at 300—100 m. Station 70 yielded none of this species. At Station 71, the percentage is small, but the volume of the sample so great that the total number of *P. m.* is rather large. On the extreme verge of the Shetland Bank there is a high percentage of *P. m.* It is interesting to note the great numbers of a single stage. Stage IV is very numerous, but there are practically none of the lower stages, and only a few V—VI. On the bank itself we find all stages together. There were many VI♀.

Comparing the section Stations 67—74 with Stations 1—14, we find that the Stations 4—7, which lie on the edge not far north of St. 72, also yielded many St. IV of *P. m.* It is remarkable that we find great numbers of Stage IV along the edge at different times.

KRAEFFT (1910 p. 79) has shown that Stage III increases in numbers towards the surface as compared with the larger stages. Stages I—II keep to the surface. KOEFOED (1908—09 p. 270) found juniores at 800—1000, the older stages being most common at 480—600 m. depth. This agrees but ill with the results of KRAEFFT's and the "Michael Sars" investigations. Fig. 11 shows the distribution of the stages after counting through the material. Stages I—III are found in by far the greatest numbers at 50—0 m. Stage IV has its maximum at 100—0 m. Stage V increases in numbers as we move down to deeper water; its lowest percentage is found at 50—0. Stage VI♀ is evenly distributed down to 300 m. The curve for vertical distribution is drawn from widely different localities. It would have been valuable to have observations from definite spots, but the curve for all stations together gives a useful general view.

The vertical distribution of *P. m.* corresponds pretty closely to that of *Calanus finmarchicus.* In the case of both species we meet with higher stages as we move farther down into deeper water layers. Stage VI of *Calanus finmarchicus* had its main level of distribution at 100—50. Stage VI of *P. m.* was found evenly distributed from 500—0.

Great variation was noticed in the size of *P. m.* This is due to the different types, which were, indeed, at first regarded as distinct species. It is doubtless possible that the causes of variation in size are the same as those in the case of *Cal. fin.*

Euchæta norvegica Boeck.

In going through the material from the "Michael Sars" Expedition no other species of *Euchæta* were found besides *E. norvegica. E. barbata* was found in the deep haul at Station 71, but was not among the 100 which were counted.

E. glacialis was not observed during the counts. One might suppose, as WITH (1915 p. 172) and JESPERSEN (1923 p. 126) do, that this species is lacking in Davis Strait.

Euchæta is, even in the lowest copepodite stages, easily distinguishable from the other copepods. I have not been able to effect any determination of the separate species in their smaller copepodite stages.

Table E shows the distribution of the different stages. The percentage of *Euchæta* is very low at all stations.

Between Norway and the Færoes, occasional specimens are found in the samples below 100 m. Station 13 has one small specimen from 50—0. Station 24, south of Iceland, had 17 % *Euchæta*, Stage II—III, at 100—50 m. Temperature and salinity are 7°.65—9°.55, and 35.21 ‰—35.14 ‰.

Table E. Table showing distribution of stages of Euchæta norvegica at all stations.

Station	Depth in m.	I	II	III	IV	V	♀	♂
1	300—0	..	..	..	..	1	..	..
3	150—0	..	..	..	..	1?	..	..
4	300—0	—	—	1	—	..	..	..
6	400—200	—	—	1	—	..	..	..
7	350—250	—	—	—	1	—	—	—
8	300—100	—	—	—	1	—	—	—
8	300—0	—	—	—	1	—	—	—
9	300—100	..	..	..	..	2?	1	..
9	300—0	—	—	1	—	..	..	..
12	300—100	..	..	1	..	1	..	..
13	300—50	..	..	1?	..	..	..	..
13	50—0	—	—	1	—	..	..	..
22	800—500	5	2	1	..	..	2	..
22	500—300	..	2	..	..	1	2	..
22	300—100	..	..	..	..	2	..	..
22	100—50	..	..	..	..	4	..	..
22	50—0	..	..	..	..	1	..	..
23	800—500	2	2	2	..	..	1	..
23	500—300	..	3	1	..	..	..	..
23	300—100	..	1	3	..	..	..	..
23	100—50	..	..	..	4	6	3	..
23	50—0	..	..	..	2	1	..	..
24	100—50	..	4	13	..	..	..	..
24	50—0	..	..	1	..	..	..	..
27	800—500	..	..	2?	..	1	1	..
27	500—300	—	—	—	1	—	—	..
27	300—100	..	..	..	..	6	2	..
27	100—50	..	..	1	1?	..	..	..
28	1500—800	..	1	..	..	..	..	..
28	800—500	..	..	1	..	1	..	..
28	500—300	..	1	1	..	3	..	..
28	300—100	..	..	..	4?	2	..	..
28	100—50	..	2	..	..	..	..	..
29	1500—800	..	..	..	..	..	1	..
29	500—300	..	..	..	..	..	1	..
29	300—100	2?	1	..	2	..	..	..
29	100—50	..	..	..	1	..	..	..
29	50—0	..	..	1	..	..	..	..
66	800—300	..	1	..	..	..	..	..
66	300—100	..	..	1	..	..	..	..
66	100—50	..	..	1	..	..	..	..
32	300—100	..	..	..	..	1	..	..
32	100—50	..	..	1	3	6	..	..

Table E (continued).

Station	Depth in m.	I	II	III	IV	V	♀	♂
33	60—20	..	..	..	..	1	..	..
37	300—100	..	..	..	..	..	..	1
38	100—50	..	..	..	1	..	..	..
40	300—100	..	..	..	..	3	..	..
41	500—300	..	..	1	..	1	..	..
41	300—100	..	..	1	..	..	..	..
41	100—50	..	..	1	..	..	..	..
42	500—300	1	..	1	..	..	..	..
42	300—100	..	1	..	..	..	..	..
43	500—0	..	1	..	..	..	..	..
43	500—300	..	2	..	..	..	..	..
46	300—100	..	1?	..	..	..	..	..
49	750—500	..	1	..	..	..	2	..
49	500—300	..	..	1	..	..	..	..
49	300—100	..	..	..	..	1	..	..
49	100—50	..	..	1	..	..	..	..
58	500—300	..	..	1	..	..	..	..
58	300—100	..	..	..	1	4	..	..
58	100—50	..	..	1	5	2	..	..
59	300—100	..	..	..	4	3	1	..
59	100—50	..	..	..	3	..	..	..
60	200—100	..	..	..	2	3	..	..
60	100—50	..	..	1	..	..	..	..
63	100—50	..	..	..	4	1	..	..
69	200—100	..	..	..	..	1	..	..
69	100—50	..	..	1	..	..	..	..
70	300—100	..	..	..	1	1	..	..
70	100—50	1	..	..	..	5	..	..
70	50—0	..	..	..	1	..	..	..
71	300—100	..	..	..	2	..	1	..
72	175—100	..	..	1	..	..	..	..

Stations 22—23 and 27—29 are closely related Atlantic stations. We find here, in addition to *E. norvegica*, St. V—VI, also many small copepodite stages which appear to belong to this species. It is possible that the smaller copepodites may belong to other *Euchæta* species. Fig. 12 shows the vertical distribution of the different stages at these stations according to the percentages as counted. It is notable that the smallest copepodite stages are found in deeper water than the larger ones.

We have here then, the opposite of what we find in *Calanus finmarchicus* and *Pseudocalanus minutus*, where the smallest stages were met with in the upper water layers. It is hardly likely that this should be due to diurnal vertical migra-

tions, as most of the stations were taken in the middle of the day. Station 23 was taken at 5 p.m. Here, there is the possibility that the older stages may have moved up. Several specimens of *Euchæta* were taken at Station 23. The Table shows vertical the distribution of stages:

Table F. Station 23.

Depth	St. I	II	III	IV	V	VI
800—500 m.....	7	13	3	4	3	3
500—300 m.....	..	7	2	2	..	..
300—100 m.....	..	8	10	1	14	1
100—50 m.....	..	..	..	13	21	8
50—0 m.....	..	..	..	3	20	5

There is, as we see, a gradual increase in the numbers of the stages as we approach the surface. Stages I—III are found only at 800—300 m., whereas Stage V occurs almost exclusively in the upper 300 m. The number of specimens investigated from this and the other Atlantic stations is rather small for any certain determination of the proportions. The result does not agree with those of previous investigations. Gran (1902 p. 96), Wolfenden (1904 p. 133) and With (1915 p. 166) found the smaller copepodite stages near the surface.

In Greenland waters, *E. norvegica* is found scattered about at practically all stations, at depths below 50 m. The percentage is low. At the northernmost stations 41—49 only young specimens were taken. With (1915 p. 162) has observed spawning in Davis Strait at the end of June and beginning of July.

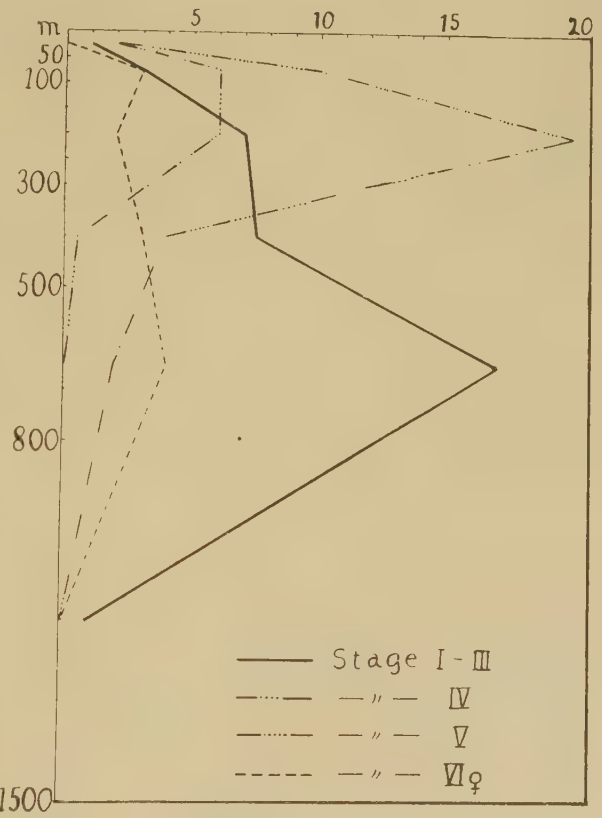

Fig. 12. Vertical distribution of the different stages of *Euchæta* at Stations 22—23 and 27—29.

Microcalanus pygmæus G. O. Sars.

With (1915 p. 69) considers that the two species *M. pygmæus* and *M. pussillus* are possibly identical. He reckons them as one species. In the present material it has likewise proved impossible to maintain any separation of the two species. In many of the specimens examined it was found that the exopodite on the 2—4th pairs of legs was not preserved.

Geographical distribution.

Microcalanus is found at practically all stations. From the stations between Norway, the Færoes and Iceland we find it of frequent occurrence in the samples from water layers between 300 and 50 m.

The cold water layers deeper down appear, from the few samples taken, to be poor in *Microcalanus*. The deep hauls from St. 4, 8, 10, 71 have at the outside 6 % of the species. Station 12 has a small percentage at 300—100 m. where the temperature is < 2. At Station 2, two specimens were counted, from 25—0 m. Stations 72, 74, yielded specimens from 50—0. Stations 2, 72, 74 were taken at night. There is thus a possibility that *M. p.* makes diurnal vertical migrations, but the material is not extensive enough to decide the point. It might be imagined that the organisms had been brought into the upper water layers by the current. At the Atlantic stations, this species is found at all depths from 100 m. downwards. At St. 66, we had 10 % in the sample from 100—50 m. The temperature here was $> 9°.34$.

On the west coast of Greenland, few *M. p.* are found. Those taken were from below 50 m. Stations 42, 43 had 10 17 % from 100—50 m. At these northerly stations, *M. p.* keeps to very low temperatures. At St. 43, 100—50 m., where we found 17 % of *M. p.*, the temperature was —1°.52 to —1°.64. In Greenland waters, *M. p.* is found chiefly in the colder water layers. The warm Atlantic water is poor.

Metridia longa Lubbock.

This species is reckoned among the most characteristic ones in the arctic. Its geographical distribution is well known. (cf. Farran 1910 p. 70).

On the "Michael Sars" Expedition in 1924, it was found at most of the stations. The stations east of Iceland had as a rule small quantities at 300—50 m. The samples from deeper water layers in the Norwegian Sea showed small percentages. This may be due to the relatively large numbers of *Calanus finmarchicus*. At St. 8 we had, from 300—100 m., 27 % of *M. l.* At St. 72 and 72, which were taken at night we found the species at 50—0. This is probably due to diurnal vertical migrations. The Atlantic stations yielded no adult specimens of this form. At St. 23 we found 2 ♂ at 800—500 m.

In the Greenland waters, *M. l.* occurs in fair quantities below 100 m. The numbers increase to the northward. At the northernmost stations we found some specimens also at 100—50 m. This agrees with the view put forward by Damas and Koefoed (1908 p. 407) that the organisms are found nearer the surface as we approach the more arctic localities. The species is found at the lowest temperatures. The sample from 250—100 m. Station 44, where the temperatures was —1°.53 to —1°.68, had 15 %. At Station 49, all stages of *M. l.* were found at depths from 750 m. upwards.

Metridia lucens Boeck.

Metridia lucens has a more southerly range of distribution than *M. longa.* It is not met with in Arctic waters. No specimens were noted from the Greenland stations. Between Iceland, the Færoes and Norway, *M. lucens* appears in the present material more especially in Gulf Stream water. It occurs in small quantities on or just outside the banks. The cold stations 10—13, north of the Færoes, yielded none of this species. Here and there among the Atlantic stations we find a few per cent. of the species.

It is a known fact that *M. lucens* moves up towards the surface at night. At our night station 74 we had 12 % of adult specimens from 50—0; no adults were taken in deeper water.

At St. 66, south of Iceland, there were many copepodites of *Metridia* between 1500—50 m. At 300—100 there were 53 %.

Acartia longiremis Lilljeborg et **Clausi** Giesbrecht.

These two species are only found in any considerable numbers from the samples in the section Færoes-Shetlands-Norway. On the bank near the Færoes, it was mostly *A. longiremis* that was found, with only a few *A. clausi.* In the deep water between the Færoes and Shetlands these species are lacking. This agrees with previous results. (cf. Farran 1910 p. 77, 79). Off the coast of Norway, few *Acartia* were found, 6 specimens from 50—0 at St. 6 were *A. Clausi.* The others were not precisely determined. Few specimens of the genus were found in the Greenland waters. At St. 47, 50—0 m., 6 specimens of *A. longiremis* were noted. At St. 66, 50—0 m., 6 specimens of *A. Clausi.*

Temora longicornis Müller.

was found for the most part on the bank at the Færoes. It was not observed in the Greenland waters.

Scolecithricella minor Brady.

This species was not observed in our counts from stations off the coast of Norway. Station 24, off the coast of Iceland, had 6 %. At the Atlantic stations, the species was found in most of the samples. The majority of the organisms seemed to keep to depths from 300—50 m.

In the Greenland waters, *S. minor* is found more especially at the most oceanic stations. The species was taken at stations farthest from the coast, such as St. 32, 38, 41, 42, 58, 59. The temperature as a rule is $> 3°$. At Station 46, one specimen was noted at 100—50 m. where the temperature was —1°.0 to —1°.23. Damas and Koefoed state that the species is met with in both temperate and cold water. (1908—09 p. 397).

Oithona helgolandica Claus.

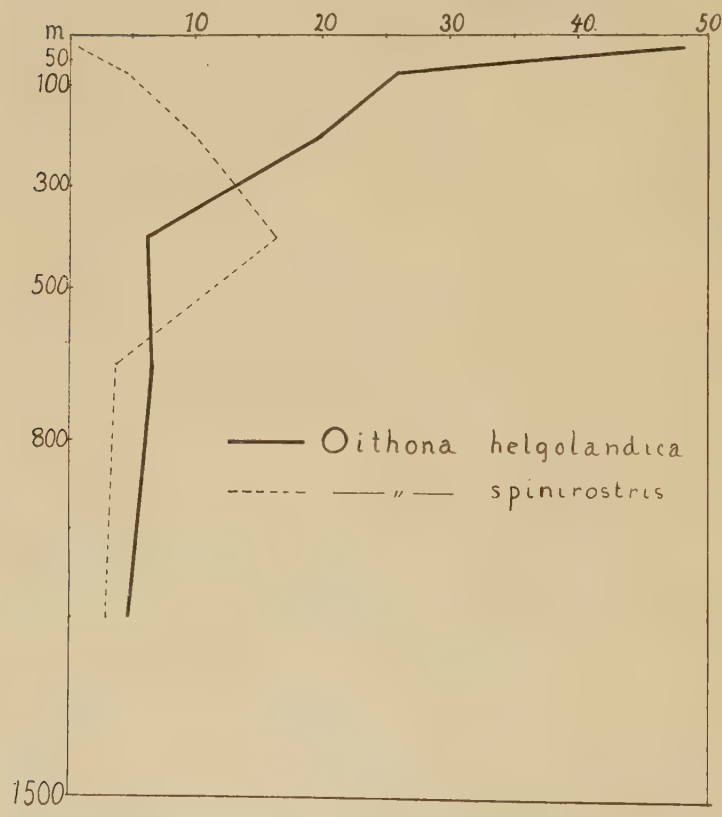

Fig. 13. Mean vertical distribution of *Oithona helgolandica* and *O. spinirostris*.

Oithona helgolandica is the name used by G. O. Sars in his description (1913). The species has generally been referred to as *Oithona similis*.

Of the genus *Oithona* we found, besides *O. helgolandica*, also *O. spinirostris*. The two species are easily distinguishable when fully grown, but while at the small copepodite stages, *O. spinirostris* is easily mistaken from *O. similis*. The percentage of both species may therefore be somewhat inaccurate when there are small copepodites present.

O. helgolandica is found in great num-

bers at nearly all stations. The species was equally common in the cold Greenland waters and in the warmer Atlantic.

From the systematic hauls made on the cruise of the "Michael Sars" it is the vertical distribution which is more particularly interesting in the case of this species. In Fig. 13, the curve shows the average percentage of the species at the different depths for all stations. At 50—0 *O. helgolandica* amounted to no less than 48.2 % of all the copepods counted. The curve shows that the species has its principal level of distribution at 50—0. Deeper down, the numbers rapidly decrease. Between 1500 and 300 we find fairly even quantity.

The curve for absolute numbers of *O. helgolandica* will take a somewhat different form from that for percentage. The latter gives the quantity in proportion to other copepods. At 500—50 we find an assembly of other copepods which reduces the percentage of *O. h.* The absolute number of *O. h.* at 500—300 will be somewhat in excess of that indicated by the percentage curve.

Oithona spinirostris Claus.

This species, in contrast to the foregoing, has a more restricted distribution.

Between Norway and the Færoes, *O. spinirostris* is met with in small numbers. The richest samples, with 6—11 % of this species, are from the margin of the Gulf Stream water. The Atlantic stations between Greenland and the Færoes are rich in *O. spinirostris*. It is found right down to 1500—800 m.

In Greenland waters, the distribution of this species is of limited extent. It is common in the south, in the warm Atlantic water. It follows this Atlantic water, which lies beneath the colder water from the north and west. At St. 41, in Davis Strait, we found 25 % at 300—100 m. Four specimens were also counted from 100—50, where the temperature was negative. This must be regarded as exceptional. *O. spinirostris* was found as a rule only at temperatures over 3—4°. The salinity was as a rule over 34 ‰.

At the northernmost stations, *O. spinirostris* was altogether lacking. This agrees well with Damas and Koefoed's results (1908—09 p. 396) from Greenland. They show that *O. helgolandica* (= *O. similis*) is more arctic than *O. spinirostris*. *O. helgolandica* occurs together with *Calanus hyperboreus*, whereas *O. spinirostris* goes with *Calanus finmarchicus*.

In the section from the Færoes-Shetlands-Norwegian Channel, *O. spinirostris* was found more especially in the Gulf Stream water on the bank.

Fig. 13 gives the curve for vertical distribution of *O. spinirostris*. Comparing it with that for *O. helgolandica*, we find an essential difference in the distribution. *O. spinirostris* is rare in the upper 50 m., and has its maximal range from 500—300 m. Farran (1910 p. 103) mentions that *O. atlantica*, which is the same species, occures more especially at 300—100 m. At Station 73, we find, as an exception, 19 % of the species at 50—0 m.

Oncea borealis G. O. Sars.

Besides this species, several others of the genus *Oncea* were also found. It proved very difficult to determine the other species, and I have therefore taken them all together under the heading of *Oncea* sp.

O. borealis was found at the cold stations 10—13, north of the Færoes. Station 12 yielded, in a haul from 300—100 m., where the temperature was below 2°, 36 % of this species. ♀ and ♂ were found. In many cases, copulation was observed.

At the Atlantic stations, the species was only taken in the deepest hauls.

It is very common up in Davis Strait. It has its greatest distribution below 100 m. It seems as if the organisms here, as pointed out by Damas and Koefoed (1908—09 p. 406) come nearer and nearer to the surface as they move farther up into the more arctic waters.

At the cold stations 42—46, *O. borealis* was taken in all samples. It was lacking at the warmest of the Greenland stations.

Between the Færoes and Shetlands, the species was found at St. 71, where we had 21 % from the cold water at 1300—500 m.

Considering the distribution of *O. borealis* in the present material, we find that it completely substitutes *Oithona spinirostris*. In the warmer water layers, we find *Oithona spinirostris*, whereas *Oncea borealis* takes its place in the more arctic waters.

The other *Oncea* species were found in deep water, especially at the Atlantic stations.

The remaining copepods are of far less importance among the plankton than those above noted, and will not be separately dealt with here. Their distribution will be best seen from the tables. It may be mentioned that at St. 46, in the deepest hauls, from 800—500 and 500—300, we found a species answering to v. Bremens description (1908 p. 227) of *Heterorhabdus major*.

This species is said to be found in the Atlantic; we should not expect to find it at an arctic station like this, north of the ridge in Davis Strait.

Biological Laboratory, University of Oslo,
26 May 1926.

Station	1				2			3	
Date	9/7				10/7			10/7	
Hour	10 a. m.				1 a. m.			10 a. m.	
Depth in m.	300 0	300 0	200 100	50 0	140 0	100 50	25 0	150 0	600 300
Volume	28	10	1,2	4,5	14,1	4,5	6,8	7	87
Calanus finmarchicus sum.	59	53	38	39	46	87	43	65	81
nauplii	12	11	3	12	..	..	..	1	..
st. I	7	10	1	16	..	..	..	..	..
- II	4	11	2	8	2	..	1	1	..
- III	1	3	2	..	..	..	..	1	..
- IV	4	1	4	1	2	10	2	9	24
- V	29	12	16	..	23	64	28	45	57
- VI ♀	2	5	10	2	19	8	12	7	..
- VI ♂	..	..	..	..	..	5	..	1	..

Station	11		12		13		14		16
Date	12/7		12/7		13/7		14/7		16/7
Hour	5^{30} p.m.		9^{50} p.m.		6^{30} a.m.		0 p.m.		12^{45} p.m.
Depth in m.	300 100	50 0	300 100	50 0	300 50	50 0	150 50	50 0	300 0
Volume	14,5	34,5	25,5	45	15	65	6,5	77	49,5
Calanus finmarchicus sum.	44	38	11	46	18	8	7	73	47
nauplii	..	1	..	..	..	..	..	7	7
st. I	..	..	..	..	..	..	..	1	1
- II	..	3	..	1	..	..	1	4	2
- III	1	6	..	1	..	..	1	4	4
- IV	20	26	11	24	11	6	1	4	2
- V	22	2	..	19	6	2	2	51	29
- VI ♀	1	..	..	..	1	..	2	2	2
- VI ♂	..	..	..	..	..	..	..	..	..

Station	28								
Date	30/7								
Hour	11 a.m.								
Depth in m.	1500 800	800 500	500 300	300 100	100 50	50 0	1500 800	800 500	500 300
Volume	3	8	9,5	5	4,6	4,6	6,1	14	5-10
Calanus finmarchicus sum.	27	36	26	37	66	10	7	18	18
nauplii	1?	..	..	..	1	3	..	..	..
st. I	..	1	..	..	..	3	..	..	..
- II	..	..	2	1	..	1	..	..	..
- III	..	..	..	..	..	..	..	..	..
- IV	..	..	..	..	..	1	..	..	..
- V	25	34	24	36	42	2	6	17	16
- VI ♀	1	1	..	..	20	..	1	1	2
- VI ♂	..	..	..	..	3	..	..	..	..

6			7				8				9			10		
$^{11}/_{7}$			$^{11}/_{7}$				$^{11}/_{7}$				$^{11}/_{7}$			$^{12}/_{7}$		
5 a.m.			0^{30} p.m.				6^{30} p.m.				11^{40} p.m.			11 a.m.		
400 200	300 0	50 0	350 250	200 100	50 0	300 0	800 500	300 100	300 0	50 0	300 100	300 0	50 0	800 500	300 100	50 0
25	23,5	29,5	2,7	12,5	3,7	81	26,5	7	21	21	2,2	4,3	15,5	0,5	6,5	50
48	21	49	15	77	13	81	49	19	32	59	14	16	22	75	18	51
..	..	4	..	..	5	..	..	..	3	1	..	5	2	..	..	1
..	..	..	..	..	3	..	..	..	1	1	..	1	3	..	..	..
..	..	..	..	..	3	..	..	..	..	..	..	2	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
14	6	20	4	18	..	12	29	10	5	3	5	2	2	42	13	5
34	15	23	11	54	2	68	20	9	23	51	8	6	14	33	5	44
..	..	2	..	5	..	5	..	..	..	3	1	..	..	..	..	1
..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..

23							24			26		27				
$^{20}/_{7}$							$^{21}/_{7}$			$^{21}/_{7}$		$^{29}/_{7}$				
5 p.m.							6 a.m.			4 p.m.		11 a.m.				
100 50	50 0	800 500	500 300	300 150	100 50	50 0	180 100	100 50	50 0	100 50	50 0	800 500	500 300	300 100	100 5	50 0
5,2	16,2	6	5,2	4,5	6	11	7,6	1,6	..	18	7,4	8	4	11	3,5	5,3
20	18	44	44	21	31	86	84	53	54	55	26	29	32	19	83	8
..	2	..	..	..	..	..	..	..	25	+	++	..	..	..	..	1
..	..	..	..	..	..	..	..	..	18	2	13	..	..	..	..	..
..	..	..	..	..	..	..	..	..	2	10	9	..	..	..	..	..
..	..	..	..	..	..	..	..	..	4	16	3	..	..	..	..	..
..	..	..	..	..	..	2	..	..	2	9	..	1	1	..	1	1
14	15	41	44	19	8	39	77	44	3	10	..	27	29	11	36	3
6	1	2	..	1	23	45	..	4	..	5	1	1	1	1	46	2
..	..	..	..	1	..	..	5	5	..	1	..	..	1	7	..	1

31	32			33		37			38			39		40		
$^{1}/_{8}$	$^{3}/_{8}$			$^{4}/_{8}$		$^{6}/_{8}$			$^{7}/_{8}$			$^{8}/_{8}$		$^{8}/_{8}$		
p.m.	6 p.m.			5 p.m.		7 p.m.			9^{30} a.m.			6 a.m.		11^{15} a.m.		
50 0	300 100	100 50	50 0	60 20	15 0	300 100	100 50	50 0	250 100	100 50	50 0	90 50	50 0	300 100	100 50	50 0
),5	(35)	9,5	42	..	..	34,5	..	..	..	7	..	4,3	..	< 7	7,5	3,4
40	1	32	75	52	2	60	..	12	22	37	39	50	..	57	77	21
35	..	..	..	..	..	..	..	+	..	..	+	+	..	..	..	2
4	..	..	..	..	1	..	..	2	..	..	1	1	..	..	1	3
1	..	..	..	1	..	..	..	9	..	..	3	3	..	1	17	2
..	..	..	1	23	1	1	..	1	..	..	4	13	..	6	52	13
..	1	2	7	27	..	3	..	..	2	3	18	27	..	27	6	1
..	..	4	67	1	..	52	..	..	18	33	13	5	..	20	1	..
..	..	26	..	..	..	4	..	..	2	1	..	1	..	8	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Station	41				42				
Date	8/8				9/8				
Hour	8 p.m.				6 a.m.				
Depth in m.	500 300	300 100	100 50	50 0	500 300	300 100	100 50	50 0	500 0
Volume	8	6,8	3,6	17	7,5	20	6,6	8,5	30
Calanus finmarchicus sum.	12	16	40	20	2	4	12	7	5
nauplii	..	..	..	+	+	..	..	..	..
st. I	..	..	..	1	..	..	..	..	..
- II	..	..	1	2	..	..	..	2	2
- III	5	..	4	13	..	..	..	3	1
- IV	1	9	18	4	2	..	..	1	1
- V	3	5	15	..	..	3	11	1	..
- VI ♀	3	2	2	..	..	1	1	..	1
- VI ♂	..	..	..	..	..	..	..	..	..

Station	49					54			
Date	15/8					16/8			
Hour	6 a.m.					9 p.m.			
Depth in m.	750 500	500 300	300 100	100 50	50 0	150 100	100 50	50 0	800 500
Volume	27	23	27	4,5	2,5	7	8,5	5	10
Calanus finmarchicus sum.	10	13	19	21	11	54	62	10	16
nauplii	..	..	..	..	..	..	..	..	..
st. I	..	..	..	..	3	..	..	4	..
- II	..	..	..	..	1	..	..	1	..
- III	1	5	2	4	3	8	13	3	..
- IV	..	1	10	12	4	21	36	2	..
- V	7	6	6	5	..	21	11	..	14
- VI ♀	2	1	1	..	..	4	2	..	2
- VI ♂	..	..	..	..	..	..	..	..	..

Station	66					67		68	
Date	26/8					2/9		2/9	
Hour	6 a.m.					10 a.m.		12[30] p.m.	
Depth in m.	1500 800	800 300	300 100	100 50	50 0	100 50	50 0	100 50	50 0
Volume	8	7	2	1,8	10	5	4	6	2,5
Calanus finmarchicus sum.	..	8	..	1	1	1	...	4	4
nauplii	..	..	..	..	..	..	..	+	+
st. I	..	..	..	..	..	..	..	..	..
- II	..	..	..	1	..	..	..	..	..
- III	..	..	..	..	1	..	..	..	1
- IV	2	4	..	..	..	1	..	..	..
- V	5	4	..	..	..	..	..	1	3
- VI ♀	..	..	..	..	..	..	..	2	..
- VI ♂	..	..	..	..	..	..	..	1	..

44			45			46					47			48		
13/8			13/8			13/8					14/8			14/8		
7 a.m.			12¹⁵ p.m.			11³⁰ p.m.					2 p.m.			8 p.m.		
250	100	50	150	100	50	800	500	300	100	50	300	100	50	300	100	50
100	50	0	100	50	0	500	300	100	50	0	100	50	0	100	50	0
27	7,5	33	3	12	< 16	9	6	0,5	12,4	50	14	6,7	12,7	20	5,5	26
16	6	10	2	4	8	1	8	11	7	11	28	41	8	16	27	10
..	1	3	2	1	..	1	1	2	6	1	..	..	2	..	..	..
..	1	2	..	..	1	..	1	..	..	..	..	..	..	..	..	..
..	..	..	..	..	2	..	..	..	..	4	..	9	2	..	..	..
..	1	1	..	..	5	..	3	4	..	6	7	24	2	5	7	4
1	..	..	..	1	..	..	..	1	..	..	15	8	2	5	11	5
14	3	4	..	2	..	..	2	3	1	..	5	..	..	5	9	1
1	..	..	..	..	..	..	1	1	..	..	1	..	..	1	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

59			60			61	62			63		64		
18/8			18/3			19/8	19/8			21/8		22/8		
11³⁰ a.m.			3 p.m.			7 a.m.	10 a.m.			3 p.m.		11 a.m.		
300	100	50	200	100	50	35	300	100	50	100	50	300	100	50
100	50	0	100	50	0	0	100	50	0	50	0	100	50	0
12	14,5	6,5	8,7	14,3	18,5	..	36	..	..	4,5	24	34	..	..
21	81	17	72	85	27	20	49	31	18	36	78	76	39	2
..	..	..	..	..	..	..	..	..	2	..	..	..	..	..
..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	4	..	..	2	..	..	..	..	..
..	..	..	..	..	2	8	..	5	5	..	..	..	3	1
.	4	6	3	6	10	8	4	15	9	1	1	10	21	..
20	64	11	64	76	14	..	39	10	..	15	76	66	15	1
1	13	..	5	3	..	..	6	1	..	20	1	1	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

70			71					72			73		74		
2/9			3/9					4/9			4/9		5/9		
10 p.m.			9 a.m.					2³⁰ a.m.			12 a.m.		12³⁰ a.m.		
00	100	50	1300	500	300	100	50	175	100	50	100	50	200	100	50
00	50	0	500	300	100	50	0	100	50	0	50	0	100	50	0
..	..	40,5	73	15	13,5	..	< 1	3,5	1	1,5	17	4	3	1	7
22	62	97	44	49	51	84	16	1	1	10	40	9	15	18	18
..	..	..	..	..	..	..	1	..	..	..	2	..	..	..	..
..	..	..	..	..	..	..	1	..	..	..	3	..	..	1	1
	..	..	..	..	..	..	1	..	..	..	1	..	..	1	..
..	..	..	..	..	..	..	2	..	..	2	..	..	..	..	..
1	2	4	20	3	..	5	..	..	..	..	18	9	10	13	1
21	57	88	24	46	45	78	11	1	1	6	13	8	4	2	16
	3	5	..	..	6	1	..	..	..	3	1	2	1	..	..
.	..	..	:	..	..	..	..	..	..	1	..	..	..	..	..

Station	1				2		
Depth in m.	300 0	300 0	200 100	50 0	140 0	100 50	
Pseudocalanus minutus st. IV	..	..	..	..	..	..	
— — - V	..	1	7	..	14	3	
— — - VI	..						
Calanus hyperboreus	..	..	..	..	..	..	
Microcalanus pygmæus	4	11	31	..	17	5	
Spinocalanus abyssalis	..	..	..	..	..	..	
Copepodit. et naupl. of macrocalanidæ	..	..	..	..	..	..	
— - — - microcalanidæ	7	10	7	2	8	1	
Metridia longa	2	..	3	..	..	..	
— lucens	..	3	1	..	2	..	
— copepodits	..	..	..	..	..	..	
Euchæta norvegica	1	..	..	..	..	..	
Acartia longiremis et clausi(*)	..	1	..	3	..	..	
Temora longicornis	..	..	..	..	..	..	
Scolicithricella minor	..	..	..	..	..	..	
Gaidius tenuispinus	..	..	..	..	..	..	
Chiridus obtusifrons	..	..	..	..	..	..	
Eucalanus elongatus	..	..	..	..	..	..	
Pleuromamma robusta	..	..	..	..	..	..	
Calanidæ indeterm	..	..	..	..	..	..	
Oithona helgolandica	27	19	10	55	12	3	
— spinirostris	..	2	3	1	1	1	
Oncea borealis	..	..	..	..	..	..	
— sp.	..	..	..	..	..	..	
Microsetella norvegica	..	..	..	..	..	..	

Station	9			10			11	
Depth in m.	300 100	300 0	50 0	800 500	300 100	50 0	300 100	50 0
Pseudocalanus minutus st. IV?	6?	..	..	..	..	..	..	3
— — - V	5	2	3	10	7	10	..	16
— — - VI			..	..	..		..	
Calanus hyperboreus	..	..	..	1	..	..	3	..
Microcalanus pygmæus	35	9	1	1	38	..	11	..
Spinocalanus abyssalis	..	..	..	1	..	..	..	..
Copepodit. et naupl. of macrocalanidæ	..	..	..	..	..	..	..	..
— - — - microcalanidæ	2	6	5	..	2	5	..	5
Metridia longa	11	8	2	..	16	..	4	..
— lucens	1	..	..	..	..	..	..	..
— copepodits	..	..	..	..	..	..	..	..
Euchæta norvegica	3	1	..	..	..	..	..	..
Acartia longiremis et clausi	1	1	..	..	..	..	..	..
Temora longicornis	..	..	..	..	..	1	..	..
Scolicithricella minor	1	..	..	..	..	..	..	..
Gaidius tenuispinus	..	..	..	..	..	..	..	..
Chiridus obtusifrons	..	..	..	1	..	..	..	..
Eucalanus elongatus	..	..	..	..	..	..	..	..
Pleuromamma robusta	..	..	..	..	..	..	..	..
Calanidæ indeterm	..	..	..	..	..	..	..	..
Oithona helgolandica	17	55	67	6	6	34	32	30
— spinirostris	5	2	..	..	11	1	..	..
Oncea borealis	..	..	..	5	2	..	4	8
— sp.	..	..	..	..	..	..	..	..
Microsetella norvegica	..	..	..	..	..	..	..	..

	5		6			7				8			
50 0	300 0	50 0	400 200	300 0	50 0	350 250	200 100	50 0	300 0	800 500	300 100	300 0	50 0
..	3?	..	20?	7?	..	51	1?	2?	3?	..	..	2?	..
..	..	3	1	2	1	1	..	..	2	17	7	2	1
..	..	..	1	..	..	..	..	..	..	2	..	..	..
..	4	..	14	11	..	21	17	..	2	6	..	7	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	1	..	..
..	..	1	1	6	2	..	..	2	3	4	1	3	1
.	..	..	2	1	..	4	1	..	..	1	27	5	..
.	..	..	18	1?	..	..	3	..	1	..	..	..	..
.	..	..	3	..	..	..	..	..	..	3	2	..	..
.	..	..	1	..	..	1	..	..	..	..	1	1	..
..	..	1	..	..	6*	..	..	3	1	..	..	..	..
..	1	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	1	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	1	..	..	..	..	..	..	..	..	..	..
.	..	..	..	1	..	..	..	..	..	..	..	..	..
.	11	34	..	50	42	4	..	78	7	7	18	46	37
.	1	..	..	..	..	3	1	1	..	..	6	2	2
.	..	..	..	..	..	..	..	..	..	1	..	..	..
.	..	..	..	..	..	..	..	..	..	20	..	..	..
.	..	1	..	..	..	..	..	1	..	..	..	..	..

14		16	21	22					24			26	
60 80	50 0	300 0	50 0	800 500	500 300	300 100	100 50	50 0	180 100	100 50	50 0	100 50	50 0
.	..	..	..	2	..	..	..	..	..	..	..	3	40
.	1	..	..		9	..	..	..	..	..	1	..	
4	..	..	..		..	..	..	..	..	..	..	..	
.	..	..	..	1	..	..	..	..	..	..	..	..	..
1	..	5	..	4	11	..	..	..	11	5	..	1	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	1	3	..	..	..	..	..	..	..	12
5	1	3	1	2		1	..	..	..	..	1	..	
.	..	..	..	4	2	..	..	..	..	..	..	..	..
.	..	..	..	..	2	..	..	..	1	1	..	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	10	5	2	4	1	..	17	1	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	5	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	..	..	..	..	..	1	6	..	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	1	..	..	..	..	..	..	..	..	..
.	..	..	..	..	..	1	..	..	..	..	..	..	..
.	..	..	..	1	..	..	..	..	..	..	..	..	..
.	..	..	..	1	..	..	..	..	..	..	..	..	..
4	20	44	53	5	13	53	55	81	1	5	42	29	21
.	..	1	..	2	24	29	21	..	2	12	1	12	1
.	..	..	..	..	..	..	..	..	..	..	..	..	..
.	..	..	..	12	17	2	..	..	..	1	..	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..

Station	23					27		
Depth in m.	800 500	500 300	300 100	100 50	50 0	800 500	500 300	300 100
Calanus hyperboreus	..	..	..	..	..	..	..	..
Copepod. et naupl. of macrocalanidæ	7	5	..	..	..	12	..	..
— - — - microcalanidæ	..	..	4	2	..	..	2	..
Pseudocalanus minutus	..	..	..	..	..	1	10	..
Spinocalanus abyssalis	2	..	1	1	..	..	..	..
— sp.(?)	..	..	..	..	..	..	..	..
Microcalanus pygmæus	8	7	12	..	..	12	2	7
Cornucalanus chelifer	..	..	..	..	..	..	..	..
Eucalanus elongatus	..	..	1	..	..	..	..	..
Rhincalanus nasutus	..	..	..	..	..	..	1	..
Xantocalanus sp.	..	..	..	..	..	1	..	2
Calocalanus sp.	..	..	..	..	..	..	..	..
Paracalanus parvus	..	..	..	..	..	..	..	..
Euchæta norvegica	7	4	8	13	3	4	1	18
Metridia longa	2	..	..	..	..	..	..	..
— lucens	..	..	..	1	..	..	..	..
— princeps	..	..	..	..	..	..	..	..
— brevicauda	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..
— copepoditer	..	..	..	..	..	..	..	..
Heterorhabdus norvegicus	..	1	..	..	..	..	1	..
— abyssalis	..	..	..	..	..	..	..	..
— sp.	1	..	..	..	..	1	..	..
Lucicutia grandis	..	..	..	..	..	..	..	..
— simulans	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..
Scolecithrix persecans	1	..	..	..	..	..	..	..
— magna	..	..	..	..	..	..	..	..
— ovata	..	..	..	..	..	..	..	..
— sp.	1	..	..	..	..	..	..	..
Scolecithrisella minor	1	1	4	2	..	1	1	1
Pluromamma robusta	..	..	2?	..	..	..	..	..
Gaidius tenuispinus	1	1	..	..	..	1	1	..
— affinis	..	..	..	..	..	..	..	..
Gaetanus kruppi	1	..	..	..	..	..	..	..
— caudani	..	1	..	..	..	..	..	..
Aetidius armatus	..	..	..	..	..	..	..	..
Haloptilus acutifrons	..	..	..	..	..	..	..	..
Acartia longiremis et clausi	..	..	..	..	..	..	..	..
Candacia sp.	2	..	..	..	..	..	..	..
Pseudophænia sp.	..	1	..	..	..	..	..	..
Calanidæ indeterm	..	..	..	..	..	..	1	..
Oithona helgolandica	..	1	18	28	9	6	3	26
— spinirostris	..	22	26	22	2	20	38	27
Oncea borealis	..	..	..	..	..	..	..	..
— sp.	..	11	3	..	..	12	..	..
Microsetella norvegica	..	..	..	..	..	..	..	..
Conea rapax	..	1	..	..	..	..	..	..

28				29						66				
500 300	300 100	100 50	50 0	1500 800	800 500	500 300	300 100	100 50	50 0	1500 800	800 300	300 100	100 50	50 0
..	..	..	..	3	1	..	..	..	..	..	..	..	..	..
..	..	1	..	21	13	..	..	..	1	4	6	3	4	1
8	..	..	..	..	..	8	..	1	..	1	6	3	1	3
..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
..	1	..	..	..	..	..	..	..	..	1	2	..	..	..
..	..	..	..	4	..	1	4	..	..	1	..	6	4	..
10	8	..	..	16	23	18	4	..	..	22	6	3	10	..
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2	13	17	89	..	6	7	35	23	91	16	14	4	12	72
39	27	8	..	1	4	40	44	5	1	7	18	14	9	4
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3	..	1	..	36	29	1	..	..	..	25	..	1	6	..
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Station	30	31	32			33		37			38		
Depth in m.	50 0	50 0	300 100	100 50	50 0	60 20	15 0	300 100	100 50	50 0	250 100	100 50	50 0
Calanus hyperboreus st. I	..	1	..	..	..	..	..	..	..	..	..	..	..
— — - II	1	..	..	..	..	..	..	..	..	..	..	..	..
— — - III	..	..	..	..	..	2	..	1	..	..	..	..	..
— — - IV	..	1	1	..	..	..	..	4	..	..	5	1	..
— — - V	2	..	..	..	..	..	..	..	..	..	..	..	..
— — - VI ♀	..	..	..	..	..	..	..	..	..	..	..	..	..
— — - VI ♂	..	..	..	..	..	..	..	..	..	..	..	..	..
Pseudocalanus minutus st. I	..	..	..	..	..	..	..	..	..	2	..	..	..
— — - II	..	..	..	..	..	..	..	1	..	3	..	..	..
— — - III	..	..	..	..	..	2	1	..	..	2	..	..	..
— — - IV	..	..	1	..	..	6	..	..	..	2	1	..	1
— — - V	..	..	..	..	..	10	1	2	..	1	4	2	9
— — - VI ♀	..	..	..	..	..	1	..	..	..	1	..	..	..
— — - VI ♂	..	..	..	..	..	..	..	..	..	..	..	..	..
Cop. et naupl. of macrocalanidæ	..	..	..	..	..	..	..	..	..	..	..	..	..
— - — - microcalanidæ	2	2	..	..	..	..	..	..	..	..	..	..	2
Microcalanus pygmæus	..	..	8	..	..	1	..	3	..	..	3	..	..
Spinocalanus abyssalis	..	..	1	..	..	..	..	..	..	..	..	..	..
— magnus?	..	..	..	..	..	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	..
Euchæta norvegica	..	..	1	10	..	1	..	1	..	..	..	1	..
Metridia longa	..	..	1	..	..	..	..	13	..	..	..	..	..
— lucens	..	..	..	..	..	..	..	..	..	..	..	..	..
— copepoditer	..	..	..	..	..	..	..	..	..	..	..	..	..
Scolecithrix ovata	..	1	..	..	..	..	..	..	..	..	..	..	..
Scolecitricella minor	..	..	2	3	1	..	1	..	..	..	2	..	..
Acartia longiremis et clausi	..	..	..	..	..	..	..	..	..	2	..	..	..
Heterorhabdus major	..	..	..	..	..	..	..	.	..	..	..	..	..
— norvegicus	..	..	..	..	..	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	..
Gaidius tenuispinus	..	..	..	..	..	..	..	..	..	..	..	..	..
Haloptilus acutifrons	..	..	..	..	..	..	..	..	..	..	..	..	..
Oithona helgolandica	68	54	56	36	24	25	95	8	..	72	45	57	51
— spinirostris	..	..	28	19	..	..	..	6	..	..	15	2	..
Oncea borealis	1	..	..	..	..	..	..	1	..	1	2	..	..
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	.
Podoplea indeterm	..	..	..	..	..	..	..	..	..	..	..	..	..

41				42				43					44			45		
500 300	300 100	100 50	50 0	500 300	300 100	100 50	50 0	500 0	500 300	300 100	100 50	50 0	250 100	100 50	50 0	150 100	100 50	50 0
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8	..	3	..	..	3	2	..	1	2	1	1	3	3	..	..	..	..	1
4	..	..	..	1	1	..	..	2	5	3	..	5	9	3	..	..	1	1
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1	..	..	6	2	..	..	6		1	..	1	5	2	4	20	..	..	15
2	..	1	13	1	..	1	11		..	..	..	11	2	4	12	..	..	16
3	..	1	7	3	..	..	9	2	1	..	2	12	..	4	8	..	4	20
..	1	1	6	4	5	7	3	6	1	4	4	6	6	4	..	1	3	9
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21	..	..	..	20	12	10	..	12	14	8	17	..	18	..	..	15	4	..
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2	1	1	..	2	1	..	..	1	2	..	..	..	..	..	..	..	..	..
16	5	..	..	..	26	19	..	4	10	36	..	..	15	..	..	11	1	..
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4	31	42	43	3	21	35	42	38	4	34	59	28	7	52	38	64	69	11
4	25	4	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
11	2	..	1	34	17	9	2	2	24	10	6	3	6	13	3	3	3	2
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Station	46					47			48				
Depth in m.	800 500	500 300	300 100	100 50	50 0	300 100	100 50	50 0	300 100	100 50	50 0	750 500	500 300
Calanus hyperboreus st. I	..	..	..	..	..	..	..	..	..	..	..	..	..
— — - II	..	1	..	..	..	..	..	..	..	..	..	..	..
— — - III	..	..	..	2	..	..	..	..	..	..	..	..	1
— — - IV	4	..	4	..	..	5	1	..	..	3	1	3	6
— — - V	3	1	3	..	..	2	..	..	1	..	..	3	2
— — - VI ♀	..	1	..	..	..	1	..	..	..	..	..	..	2
— — - VI ♂	..	..	..	..	..	..	..	..	..	..	..	..	..
Pseudocalanus minutus st. I	..	..	..	1	6								
— — - II	?	..	2?	..	4	3	1	2	5	7	11	..	1
— — - III	..	..	1	2	17		6	1					
— — - IV	2	12	4	3	13	1	15	2	2	5	5	3	2
— — - V	6	..	14	17	8	8	13	2	10	10	8	29	20
— — - VI ♀	..	..	2	1	..	3	1	..	2	1	1	..	1
— — - VI ♂	..	..	..	1	..	1	..	..	..	3	..	..	..
Cop. et naupl. of macrocalanidæ	6	5	1	..	1	..	..	..	..	..	..	1	..
— - — - microcalanidæ	6	2	3	..	..	..	..	..	1	..	..		..
Microcalanus pygmæus	37	24	9	..	..	9	1	..	11	10	..	8	4
Spinocalanus abyssalis	7?	5?	..	..	..	..	..	..	..	..	..	..	..
— magnus?	..	..	..	..	..	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	..
Euchæta norvegica	..	..	1	..	..	..	..	..	..	..	..	3	1
Metridia longa	4	6	11	3	1	25	1	..	34	14	..	21	38
— lucens	..	..	..	..	..	..	..	..	..	..	..	..	..
— copepoditer	..	..	..	..	..	..	..	..	..	..	..	..	..
Scolecithrix ovata	..	..	..	..	..	..	..	..	..	..	..	..	..
Scolecitricella minor	..	..	..	1	..	..	..	..	..	..	..	..	..
Acartia longiremis et clausi	..	..	..	..	..	..	1	2*	..	1	2	..	..
Heterorhabdus major	3	1	..	..	..	..	..	..	..	..	..	..	..
— norvegicus	..	..	1	..	..	..	..	..	..	..	..	..	..
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	..
Gaidius tenuispinus	1	3	1	..	..	..	..	..	..	..	..	..	.
Haloptilus acutifrons	..	1	..	..	..	..	..	..	..	..	..	..	..
Oithona helgolandica	3	4	17	49	33	9	18	83	14	19	60	5	..
— spinirostris	..	..	..	..	..	1	..	..	..	..	..	..	..
Oncea borealis	18	26	16	13	5	4	2	..	2	..	..	13	15
— sp.	..	..	..	..	..	..	..	..	..	..	..	..	..
Podoplea indeterm	..	..	..	..	..	..	..	..	..	..	..	..	..

58					59			60			61	62			63		64		
800	500	300	100	50	300	100	50	200	100	50	35	300	100	50	100	50	300	100	50
500	300	100	50	0	100	50	0	100	50	0	0	100	50	0	50	0	100	50	0
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6	4	1	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..
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24	8	4	..	..	5	1	..	2	..	..	..	2	..	..	..	..	8	14	..
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3	3	4	9	..	3	..	..	1	..	..	..	4	..	..	..	..	2	..	..
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21	18	22	24	39	19	9	81	15	13	69	60	6	39	74	56	22	7	39	96
9	24	26	7	2	40	3	1	4	..	..	..	2	1	..	3	..	1	4	..
6	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2
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Station	67		68		69	
Depth in m.	100 50	50 0	100 50	50 0	200 100	200 100
Pseudocalanus minutus st. I—III	6	11	12	..	..	..
— — - IV	..	3	2	..	..	..
— — - V	5	3	4	..	3	4
— — - VI ♀	4	5	1	..	..	..
— — - VI ♂	..	1	..	..	..	..
Calanus hyperboreus	..	..	..	..	..	..
Microcalanus pygmæus	..	..	..	..	23	52
Spinocalanus abyssalis	..	..	..	..	..	..
Copepodites et naupl. of Macrocalanidæ	3	8	7	11	..	..
— - — - Microcalanidæ					..	2
Metridia longa	..	..	..	..	3	..
— lucens	..	..	..	..	1	..
— copepoditer	..	..	..	..	..	1
Euchæta norvegica	..	..	..	..	1	..
Acartia longiremis	18	11	20	2	..	..
— clausi	3	..	..	..	..	..
— copepoditer	29	26	21	22	2	..
Centropages hamatus(?)	3	11	2	1	..	..
Temora longicornis	21	18	19	21	1	..
Scolecithricella minor	..	..	..	..	..	..
Paracalanus parvus	..	..	..	..	..	..
Oithona helgolandica	4	3	8	37	9	3
— spinirostris	..	..	..	..	3	2
Oncea borealis	..	..	..	..	..	..
Podoplea indeterm	1	..	..	..	..	..

	71					72			73		74		
50	1300	500	300	100	50	175	100	50	100	50	200	100	50
0	500	300	100	50	0	100	50	0	50	0	100	50	0
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..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	3	1	..	..	..
..	..	..	..	..	..	..	1	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	1	..	..
..	3	15	10	16	82	2	14	4	34	6	8	26	18
..	..	6	1	..	..	2	19	1	3	18	9	11	..
..	21	3	2	..	..	..	..	..	..	..	..	..	..
.	..	..	..	..	..	..	..	..	..	..	..	..	..

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ON THE BIOLOGY OF COPEPODS OFF MÖRE 1925—1927

BY

JOHAN T. RUUD

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Introduction.

During the first 10 years of the present century, copepods in zoo-plankton were the object of close investigation off the coast of Norway and in the neighbouring Norwegian Sea, first by Gran and later by Damas. Their results form the basis of our present views of the entire biology of plankton, and the impression they gave of the life of plankton animals and the conditions of life in the sea off our coasts agrees in the main with our present conception of these things.

Subsequent detailed investigations, however, have convinced us of the desirability of securing greater continuity in the observations, both as regards time and place, than was formerly the case. In 1925 a number of purely preparatory investigations were made from the whaling station at Aukra in Möre over the coast bank in May and July. Then in the Autumn of 1925 the plan was prepared which formed the basis of the investigations in 1926. This plan has already been dealt with in detail (Hjort 26) so that I will here only indicate its aim. The investigations at Möre in 1926 were of such a nature that at certain intervals, about 14 days, a line of stations was taken from Julsund, near our basis, the whaling station at Aukra and out to the North West to the "Storeggen" 45—50 nautical miles from land. The following stations were taken: 1. Station A in Julsund, 218 m. deep; 2. Station B in Buddypet 5′ NNW Björnsund light house, 190 m. deep; 3. Station C at Budgrund, 17′ NW Björnsund, 80 m. deep; 4. Station D on the Bank, 32′ NW Björnsund, 120 m. deep and 5. Station E on the "Storeggen", about 45′ NW Björnsund. At these Stations in addition to hydrographical observations and samples for phyto-plankton there were also taken vertical hauls with closing nets in the depths, 20—0 metres, 50—20 ms., 100—50 ms. and from 200 or the bottom to 100 ms.

Eight cruises were taken to Storeggen in 1926 during the period March 16th —July 20th.

In a preliminary report (Hjort 26, Appendix A) I gave a brief survey of the results of the year. It proved *inter alia* that *Calanus finmarchicus* at Möre spawns twice, having one spawning period in March and one in June. Even if this had not been previously observed at Möre the idea would not have been quite new, since Paulsen (09) at so early a date expressed doubt as to whether spawning of *Calanus*

took place only in the Spring around Iceland, and we know from Crawshay's Laboratory experiments at Plymouth (Lebour 16) that *Calanus finmarchicus* may complete its entire development in less than two months. Subsequently other investigators have also mentioned the possibility or likelihood of *Calanus* spawning more than once a year.

There was further a predominance of *Calanus finmarchicus* in the copepods community found in the Spring, but smaller species of Calanoids and Cyclopoids set their mark on the stock in the Summer. This also appeared from the volumes of plankton which in size corresponded more or less closely to the size of the stock of *Calanus*.

We were convinced that these conditions in the zoo-plankton were so far in conformity with the law that a comparison with the results of the following years would be fruitful even if the investigations were carried out according to a somewhat different plan than those of 1926.

In 1927 the same plan was made the basis of the work, but with the exception that the frequency of the cruises was restricted to one cruise per month and also that the Romsdalsfjord was included in the area to be investigated. There we had two permanent stations, one in the outer part of the fjord, in Forfjord abreast the Town of Molde, and one in the inner part of Romsdalsfjord. These are referred to in the tables as Stations Ffj. and Rfj. respectively. In this connection I would mention that, like the other western fjords, this fjord has a threshhold with a depth of 180 ms. just inside our Station A in Julsund. At Station Ffj. the fjord is 480 ms. deep and at Station Rfj. 400 ms. deep. In 1927 six cruises were taken over the coastal bank and three cruises in the fjord, all in the period between $^1/_3$ and $^{11}/_8$.

In these three years a long line of stations was taken out to sea in a north-westerly direction about 200 miles from Björnsund. For the purposes of comparison with the material thereby obtained this report also includes a number of observations on the material from the Michael Sars Expedition in 1924 from Stations between Norway and the Færoe Islands. The position of these Stations will appear from the map Fig. 3.

Hauls.

The present work is the result of only vertical hauls taken to the greatest possible extent at definite depths.

Nets.

The nets employed were of the same construction as those used on the Michael Sars Expedition in 1910 (further information is given in a foot note on page 32 by "Hjort and Ruud" 27). I will not enter here into a discussion of the qualities of this type of net, because an investigation with this in view has been started by Professor Mielck at Heligoland. I will merely mention that the size of the mesh

in the lower cone (Silk No. 8) is .20 mm. and in the cylindrical part (Silk No. 0) .53 mm. The first stage of *Calanus finmarchicus* nauplii according to Lebour (16) is .21 mm. long. The breadth of this stage is somewhat less, but at the same time the natatory legs are so well developed that we must assume that the majority of nauplii also of the first stage are kept back in the conical part. In the cylindrical part only the sixth stage of nauplii will be kept back. Of other species, e. g. *Pseudocalanus minutus*, nauplii less than stage 3 will pass through the meshes in the conical part of the net (Oberg 06) and all nauplii through the cylindrical part. The values given in the tables concerning nauplii must thus in any case be regarded only as minimum values.

Fixation.

All specimens were at once fixed in about 7% of Formol.

Analysis.

In the analysis of the material the only method employed was the gravimetric which had been worked out in the laboratory (Hjort & Ruud 27). The only deviation from the description there given was that two parts of the process were combined, since I determined the percentages of the differents species in the same small part of the sample (w) in which the total number is counted. As a rule only the first hundred are determined as to species and stages, whilst the remainder are only counted currently. In the above-mentioned article there is quoted an instance of 3 percentage analyses of the same sample. In addition to several such check countings I have also undertaken with smaller samples a number of total countings in order to control the gravimetric method. I will only mention at this stage that the greatest deviation from the absolute figure which I have found amounts to 2.6%. In the case of several gravimetric analyses of the same sample taken one after another, the greatest deviation found was 1.7%. It is hoped that the whole method, preferably in comparison with other methods employed, will be the object of a more thorough mathematical treatment.

Nomenclature.

In the preparation of the tables showing the results of the analyses, the nomenclature has been kept in accordance with With (15) and subsequent authors.

Determination of Species.

I have made no attempt to separate *Calanus finmarchicus* and *helgolandicus*, because the justification of the latter as a distinct species is the subject of doubt (Farran 11, With 15). Moreover any separation would be equivalent to a disproportionate increase in the work.

I have not experienced any difficulty in separating the smaller stages of

Calanus hyperboreus and *finmarchicus* from each other, because the difference in size in the Möre district is too striking. The scheme of determination of the varoius copepodite stages of *Calanus finmarchicus* is now so well known that I see no reason for repeating it here. (Gran 02, Damas 05, Paulsen 06, Lebour 16, see also Claus 63, Grobben 81, Oberg 06, Kraeft 10). As regards nauplii I have differentiated between micro and macro calanids, since by these terms I understand the same as does Störmer (this volume, pages 4 & 5). It appears from Oberg's work (06) that the difference in size between the said nauplii is sufficiently great to allow us with practice to separate them from each other. Later on in the paper, nauplii of macrocalanids are included in the curves with *Calanus finmarchicus*. This appears to be justified when we consider how predominant this species is in comparison with those with which it is conceivable that its nauplii might be confused. In addition there is the circumstance that on account of the size of the mesh of the net the minimum values obtained give an error which also works in an opposite direction to that which we have in including nauplii of other species with *Calanus finmarchicus*. Certain nauplii of larger copepods, e. g. *Euchaeta norvegica* are so characteristic that they can at once be entered under their respective species.

Figure Values.

I have made no attempt to reckon the figure values found into the number per metre of the haul, or the number per square metre of the surface, neither have I employed any correction for the net. Like Farran (27) I compare the hauls direct, also when the hauls are totalised, irrespective of the different depths at the stations. In order eventually to compare with other regions where the results are given as the number per square metre of surface, we must multiply our figures by the factor 2.6. This only takes regard to the diametre of the net and the value found is thus to be regarded as a minimum value. It then appears that e. g. the stock of *Calanus finmarchicus* at Möre and in the Gulf of Maine (Bigelow 26) are of the same order of size.

Determinations of Volume.

The determinations of volume of the samples were undertaken by sinking in measuring cylinder for 24 hours, after taking out larger animals, *euphausiidæ*, *medusæ* and the like.

Measurements.

In the longitudinal measurements of *Calanus finmarchicus* which I have undertaken I have only measured Cephalothorax at Stage V. Like Störmer I employed Leitz microscope objective 3, without front lens and ocular 2, but with a moveable micronmeter built in. The distance between two graduations thus becomes 0.0357 mm. I have generally measured from 25 to 100 specimens in

each case, the number varying according to the homogenity of the samples and the number of Stage V present. The mean value (M), its mean error (m) and the dispersion (Standard deviation, δ) are calculated and recalculated to mm. At certain stations in March from which it was desirable to have measurements but where Stage V was lacking I measured Stage VI ♀. The average value found for the length was reduced according to the following equation, VI ♀: V = 1.08, which I have found as the average of a number of measurements. Otherwise where the stock has been so small I have estimated the average value of the length of so few as nine specimens in several cases.

Tables.

The tables and curves compiled from the stations in the lines have been consequently prepared in such a manner that the most easterly station is placed to the right.

I would here take the opportunity of expressing my deep gratitude to Dr. Johan Hjort for the confidence he has shewn me in allowing me to make use of this material and for all the help he has afforded me with never failing interest during its preparation. I would also thank Dr. H. H. Gran, who has been so kind as to read through my manuscript and who has also been of invaluable help to me in clearing up and working out problems. Mr. Leif Störmer was of great assistance to me when we worked together in this laboratory. Mr. Jacob D. Sømme has helped me with the determination of Nauplii of Calanids. Finally, I would thank Mr. Andreas Ingebrigtsen, whaling manager, for all the interest and willingness he and others at the Aukra whaling station exhibited towards our work at Möre.

Material.

Number of Copepods and the Percentage Distribution of the Species.

In our material from Möre there occur 22 species of copepods. The majority of these occur in small numbers and only occasionally, in some cases very rarely. *Calanus finmarchicus* (Gunn) is the most important both on account of its large numbers and its size. Next to this *Pseudocalanus minutus* (Kr.) especially during the summer, plays a considerable part. The two species of *Oithona* occurring namely *Oithona helgolandica* (Claus) and *Oithona spinirostris* (Claus) make collectively figures which may even exceed those for *Calanus finmarchicus*. On account of their small size, however, these cannot be compared as regards importance with *Calanus finmarchicus*.

Other species such as *Acartia Clausi* (Giesbr.), *Acartia longiremis* (Lillj.) and *Microcalanus pygmæus* (G. O. S.) are nearly always present in varying numbers and are thus of a certain importance for the plankton.

The total number of copepods varies from time to time and from place to

place. To judge from the existing material this takes place at Möre according to a regular law which is only subject to comparatively small variations. This agrees moreover with earlier investigations in these regions. Thus GRAN (02), page 98 says:

"Die Verteilung des Planktons ist insoweit stabil, dass an einer bestimmten Stelle jedes Jahr im Grossen und Ganzen dieselben Arten periodisch mit dem Wechsel der Jahreszeiten auftreten und verschwinden. Die Unregelmässigkeiten, die in diesen periodischen Variationen auftreten, sind nicht viel grösser, als dass sie auch z. B. in der Verbreitung unserer einjährigen littoralen Meeresalgen oder der Thiere des Benthos vorkommen können."

Within the community of copepods the number of the various species also varies regularly according to a law which is determined by the breeding time and period of development and other biological conditions of each species. There is naturally some difference between the various stations in each line of stations, but in spite of this we can with advantage regard each line as one unit and investigate the variations in number of the copepods from one cruise to the next. In table 1 the total figures have been converted into average figures per station in

Table 1. Average number of copepods per Station, the various Dates and the Percentage of the Number of *Calanus finmarchicus*, *Pseudocalanus minutus*, *Microcalanus pygmæus* and *Oithona helgolandica*.

Year	Date	Average	C. f. %	P. m. %	M. p. %	O. h. %
1925	26-28/V	34010	47,2	23,0	9,8	8,3
	22/VII	32350	11,5	8,0	8,5	18,2
1926	16-18/III	6920	14,9	20,6	11,9	5,3
	26-27/III	5343	23,8	29,5	9,2	16,9
	9-10/IV	21363	60 9	9,0	1,6	4,7
	28-29/IV	36828	63,4	9,1	5,1	2,9
	17/V	21601	34,0	14,2	13,3	7,3
	1-2/VI	14295	43,0	12,2	14,7	4,0
	24-25/VI	23023	40,3	8,8	7,3	10,2
	20/VII	40023	28,2	31,2	7,8	23,0
1927	1-2/III	2471	13,5	15,1	33,5	10,6
	28-29/III	25016	63,4	15,1	3,2	7,9
	3-4/VI	22136	56,5	16,5	1,7	2,2
	1/VI	7326	45,5	16,3	7,1	4,8
	29/VI	14455	40,5	17,3	7,4	3,9
	31/VII	34250	15,3	7,9	1,7	21,8

each line. In addition there is recorded the percentage distribution of this figure for some of the most important copepods, namely *Calanus finmarchicus*, *Pseudocalanus minutus*, *Microcalanus pygmæus* and *Oithona helgolandica*, the last exclusive of small copepodites the species of which have not been determined.

It will be seen from this table that the total stock of copepods at the beginning of March is small. In 1927, when we lack observations for April, the stock reached its first maximum as early as the end of March, in 1926 at the end of April. The existing observations for 1925 appear to indicate that the maximum for that year was reached even later. In both of the last years the stock was at a minimum on June 1st, whereupon it again grew and reached the maximum for the year in the last cruise at the end of July. If the large stock observed at the end of May 1925 belongs to the first maximum of copepods, it must be assumed that in that year no marked intervening minimum was present. We see from the percentage figures for the species here selected that the first maximum of the stock of copepods was produced by *Calanus finmarchicus*. 63.4 % of the first maximum figures belong to the latter in both of the last years. The percentage figure for *Calanus* began in March 1926 and 1927 respectively at 14.9 and 13.5 % and then rose to a maximum of 63.4 and again decreased somewhat regularly to 28.2 and 15.3 % respectively.

As previously reported in a preliminary paper (Hjort 26 App. A) there took place in 1926 a new spawning of *Calanus finmarchicus* with a mass occurrence of nauplii from 1—6 to 20—7. As we shall see later on, this was also the case in 1927. In accordance therewith there was an increase in the number of *Calanus finmarchicus* during the same period as illustrated by figure 2. In spite of this the percentage of *Calanus* in the total stock of copepods decreased during the whole of June and July of both years, but most in 1927 when the new spawning, at any rate on the first of July, was weaker than in 1926.

In March 1926 *Pseudocalanus minutus* began with a rather high percentage which at the same time decreased with the great increase of the stock of copepods as a whole. *Pseudocalanus* reached its greatest height $^{20}/_{7}$ 26, viz. 31.2 %. In 1927 the percentage figure of the stock steadily increased from 15.1 to 17.3 in the five first cruises, but decreased until $^{31}/_{7}$ to 7.9 %. As we shall see later on, under this species *Pseudocalanus* had numerically a development which strongly resembles that of *Calanus finmarchicus*, but the first maximum was far weaker than the second in 1926. In 1927 the first maximum was strong whilst the second was apparently only at its commencement $^{31}/_{7}$. (See fig. 8).

Microcalanus pygmæus in both the last years had a percentage figure which decreased with an increasing total number of copepods and vice versa increased with a decreasing total number. We already see from this that the stock of *Microcalanus* can only be subject to relatively small variations. This is satisfactorily explained by the circumstance that *Microcalanus* as we shall see later on is most

numerous in the deeper layers of water where the hydrographical conditions are most stable.

The percentage value of *Oithona helgolandica* decreases from a relatively high value in March to a minimum at the end of April till the beginning of May, and then increases to a large maximum at the end of July. We find similar figures of the same order of size for undetermined *Oithona* copepodites. The stock of *Oithona helgolandica* has numerically speaking two maxima in the same period, but the latter in July is by far the largest and the intervening minimum not specially marked.

In 1927 *Calanus finmarchicus* also dominates the stock in the fjord. *Pseudocalanus minutus* plays therein a minor part. *Microcalanus pygmæus* is found in similar proportions as out on the bank. *Oithona helgolandica* plays a minor part in the first cruise but increases to an impressive number in the last cruise where *Oithona helgolandica* alone made up 44 % of all the copepods at Station Ffj. Otherwise there is a quite considerable stock of *Calanus hyperboreus* at these stations in the fjord. Thus 42 % of the stock at Station Rfj. $^{21}/_{6}$ belonged to this species.

Volumes of Plankton.

The variation which we find in the stock of copepods both from a purely numerical point of view and with regard to the distribution of the various species naturally marks the volumes which we find. In the following table the volumes at each station are added together and in addition the average value for each line of stations is estimated.

On the whole there were small volumes at all stations at the beginning of March in both years. At the end of March 1926 there was a slight increase at Station A which was partly due to diatoms in the upper hauls. $^{22}/_{3}$ 1927 there were already large volumes at all stations in the fjord decreasing outwards. On $^{28-29}/_{3}$ 27 the situation on the bank was similar but with even larger volumes. In 1926 there commenced the great increase at Station E on April 10th and during next cruise on April 28th—29th there were large volumes at all stations decreasing from Station D inwards. The greatest volumes were found in this cruise in 1926 and in the cruise May 3rd—4th 1927. In 1925 the volumes at the end of May were to some extent even greater. As we shall see later on in dealing with *Calanus finmarchicus* the increase in volumes coincides with the mass development of that species. By merely considering the volumes we have the impression that the increase in 1926 began first outwardly and extended inwards, whilst in 1927 the opposite was the case. Such an essential difference naturally did not exist between the two years. The development of *Calanus* has two centres, one in the coastal water near the shore and one which causes an invasion on the Storeggen. The invasion on the Storeggen in 1926 occurred before development from land characterised the volume, but in 1927 the

Table 2. Volume of Plankton in cubic centimetres at the Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1925	26-28/V	42	36	56	130	34			59,6
	27/VII	15	11						13,0
1926	16-18/III	2	2	1,5	3	10			3,7
	26-27/III	4,7		3,5	3,2	19			7,6
	9-10/IV	69	15	13,5	22	6			25,1
	28-29/IV	33,5	85	58	43	37,5			51,4
	12/V	44,5	22	33	26,5	20,5			29,3
	1-2/VI	34,5	32	33	39,5	35,5			34,9
	24-25/VI	11,5	48,5	33,5	31,5	40,5			33,1
	20/VII	23,1	26	24	33	14			24,0
1927	1-2/III	4	1,8	1,0	2,9	1,7			2,3
	22/III					23	35	35,5	
	28-29/III	13,0	8,5	24	51	49			29,1
	3-4/V	43	30	36,5	53,5	79			48,4
	1/VI	8,1	7,5	27	31,5	33			21,4
	21/VI					17,5	29,5	55	
	29/VI	57	23,5	12,5	19,5	14			25,3
	31/VII	24,5	21	14	18	9,5			17,4
	11/VIII						35,5	17,5	

opposite was the case. In both cases the maximum volumes correspond with the maximum of the stages of larger copepodites of *Calanus*. From a maximum in April—May the volumes decrease more or less evenly. Certain later large volumes are partly due to a large stock of *Calanus* as at Station E $^{29}/_{6}$ 27, and partly because during June—July there are more and more of other species of plankton in the samples, such as medusa, chaetognata and the like.

These were naturally during the determination of volume always picked out, but medusa, for instance, often fall to pieces whilst being fixed and can therefore not be effectively removed. The largest volumes on the bank are always to be found in the upper hauls from 20—0 metres and 50—0 metres respectively. This was also the case in the fjord in the first cruise on March 22, whilst in the two last cruises the maximum volume was in the deepest hauls from the bottom up to 150 metres. Figure 1 shews graphically the average volumes of each line of stations for the various years. By comparing this with the figure for *Calanus finmarchicus* and the corresponding one for *Pseudocalanus minutus* (Figure 2 and Figure 8) we at once see the striking agreement which exists. In this case the curve for 1925 also permits

the assumption that the stock in that year developed later or reached a considerably greater height than in 1926. In the latter year again the mass development began later than in 1927. It is impossible to say at present what is the primary cause of this displacement in time for the mass development of the zoo-plankton from 1925—1927, but it seems probable that it is connected with the difference in the meteorological conditions of the three years. The average temperature of the air for March at Ona, the nearest meteorological station, from 1925—1927 was respectively 1.3°, 2,2° and 4.2°. These conditions of temperature undoubtedly influence the melting of the snow and thereby the growth of diatoms during those three years (GRAN, this volume). — We understand from what has been said above that the stock of copepods in the three last years consisted of the same species which had already been described by GRAN (02) for those waters, and even if we do not obtain from his data any absolute figure for comparison, it appears clearly that the development of the stock took place in a similar manner, and likewise that the relative importance of the various species was the same then as now. The various species will be dealt with here in the following order:

Fig. 1. Average Volumes of Plankton.

1. *Calanoida.*
   A. Macrocalanoida:
      Calanus finmarchicus, Gunnerus.
      Calanus hyperboreus, Krøyer.
      Euchæta norvegica, Boeck.
      Metridia longa, Lubbock.
      Metridia lucens, Boeck.
   B. Microcalanoida:
      Acartia Clausi, Giesbrecht.
      Acartia longiremis, Lilljeborg.
      Microcalanus pygmæus, G. O. Sars.
      Pseudocalanus minutus, Krøyer.
      Temora longicornis, Müller.
      Other Calanoids.

2. *Cyclopoida.*

Oithona helgolandica, Claus.
Oithona spinirostris, Claus.
Oncæa borealis, G. O. Sars.

3. *Harpacticoida.*

Microsetella norvegica, Boeck.

1. Calanoida.

A. Macrocalanoida.

Calanus finmarchicus, Gunn.

On account of the important economic part played by *Calanus finmarchicus* everywhere where it commonly occurs, its biology in the course of the last 25 years has been the subject of intense study in many waters.

In the North European Waters the first investigations from biological points of view were undertaken by Gran (02) followed by works of Damas, Damas and Koefoed, and Paulsen.

In his comprehensive work Farran (11) gives a critical account of the view of *Calanus* biology to which the above-mentioned works led, a view which in its essential features is still the prevailing one. Much valuable work, especially with more detailed investigations, has subsequently appeared. I would here particularly draw attention to the work of Esterley, With, Willey, Bigelow, Störmer and Farran. It is, however, especially the investigations of the first mentioned which I shall more directly be able to use in comparison with my own.

Variations in Number.

The great variations in the occurrence of *Calanus finmarchicus* from a purely numerical point of view are so striking that G. O. Sars after the expedition of the "Vöringen" from 1876—78 noticed this, and mentioned the edges of the great coast banks as places with an especially rich occurrence of the same (Sars 86). All subsequent authors touch upon this point, the latest being Bigelow (26) in his investigations in the Gulf of Maine, and Farran (27) on the south coast of Ireland.

I give a number of tables from our own investigations at Möre, and deal with the conditions in the fjord, on the bank and outside the latter each separately. The figures given are the results of the countings in the samples, these being summed in such a way that the figure corresponds to one haul from the bottom to the surface. At the outermost station, Station E, the depth of the haul is from 200 metres. The last column gives the average value for the whole section.

Table 3. Total Number of *Calanus finmarchicus* in Hauls summed up from the Bottom to the Surface (The Bank).

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	Average
1925	26-28/V	10792	10999	19872	35420	3157	16048
	22/VII	4490	2970				3730
1926	16-18/III	125	0	456	852	2984	1041
	26-27/III	596		1390	242	2863	1270
	9-10/IV	24075	7328	19122	12195	2863	12995
	28-29/IV	14092	38423	30146	22082	12464	23422
	12/V	9864	5447	11263	7985	2192	7350
	1-2/VI	9959	7243	7028	6179	619	6156
	24-25/VI	3099	9781	9397	11115	13017	9282
	20/VII	5959	20184	6642	19579	4161	11294
1927	1-2/III	331	44	214	227	863	335
	28-29/III	5674	4142	18541	30065	20864	15857
	3-4/V	9399	5155	10883	18915	18169	12504
	1/VI	6684	780	2163	3456	3606	3334
	29/VI	16543	7460	918	1380	2943	5849
	31/VII	5976	8427	6226	4208	1404	5248

The Bank.

The figures give a good general picture for the various years of the explosive-like production of *Calanus finmarchicus* in April—May. The conditions can be summed up in the following way.

March. At the beginning of March there were only small quantities of *Calanus* present in the samples. There were most at Station A in Julsund and the number decreased out to Station D with a slight indication of increase at Station E.

At the end of March 1926 the situation was the same, whilst in 1927 there was a colossal increase in the number of *Calanus* present. The increase was greatest at the inner stations where, for instance, at Station B the number was 133 times as large as that which we found on March 1st. On the other hand the increase at Station E was not more than about 17 to 18 times.

April. In 1926 the increase in number began at the beginning of April, but on that occasion was greatest at Station E (about 40 times) and decreasing to Station A where the number on April 10th was the same as on March 27th. At the end of April the increase in number continued, especially at the middle stations, but decreased slightly at Station E. At Station D we had the largest number of *Calanus* counted on the bank, over 38,000 (120—0 ms).

May. We must assume that the maximum was past at the beginning of May both in 1926 and 1927, since there was a decrease in the number for that month in both years. It is not possible, however, to form a true picture of the maximum in 1927 on account of deficient observations in April of that year. In 1926, however, the number on May 12th had decreased to one-sixth of the quantity we found on April 29th. The alterations were least at Station E. In 1925 there were still larger quantities of *Calanus* at the end of May, especially at Station B and Station C, where there are 20,000 to 30,000 specimens in the hauls from the bottom to the surface.

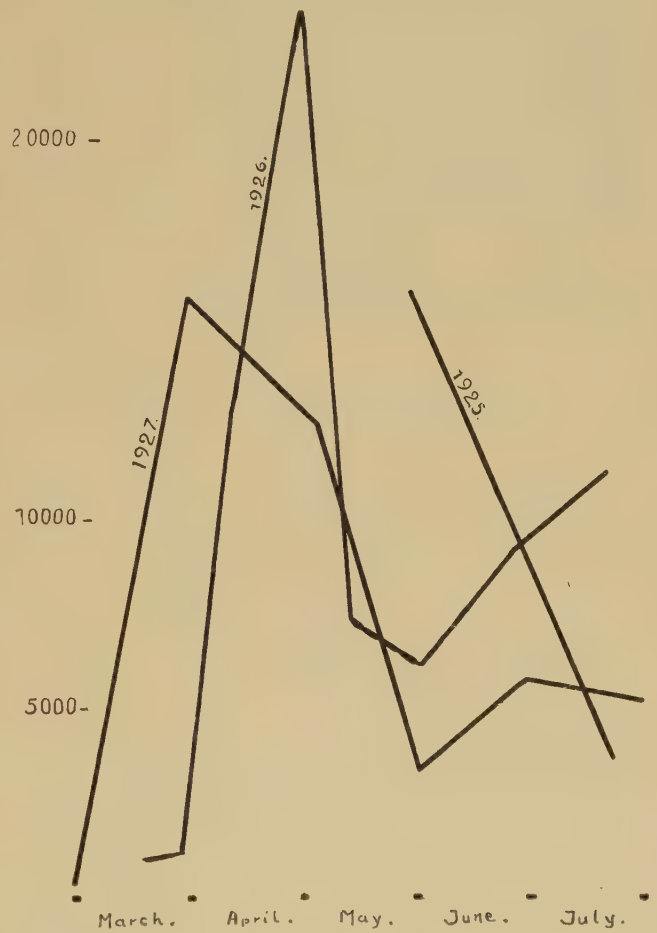

Fig. 2. The average Numbers of *Calanus finmarchicus*.

June. At the beginning of June there was a continued decrease in the number of *Calanus* both in 1926 and 1927, especially at the inner stations. At the end of June 1926 there was an increase in number at all stations except at Station E where there was a falling off. In 1927 on the contrary there was an increase at Station E and Station D, and a falling off inwards.

July. The increase in 1926 continued up to July 20th and there was then also an increase at Station E. In 1927 at the end of that month there was a decrease at Stations E and A, but otherwise a slight increase. In 1925 the figures for that month appeared to be less than those for the following years.

On the basis of the average figures from the last column in the table we can draw a curve (see Fig. 2.) shewing the variations of the average numbers for the various years. This figure gives an excellent picture of the purely numerical differences between the 3 years. It will be seen from the figure that, apart from

the incomplete curve for 1925, there are two maxima in the quantity of *Calanus*. The former is by far the most numerous and appears to fall in April, earlier in 1927 than in 1926. The curve for 1925 appears to indicate a maximum later in April—May. The intervening minimum in the two last years coincides on June 1st. The secondary maximum in June—July is larger in 1926 and appears somewhat later in 1927. It is difficult to form any opinion of the further development, but the growth of *Calanus* directly or indirectly is in connection first with the flowering of the diatoms, and later with the maximum occurrence of peridinians, which appears to give rise to the supposition that the autumn maximum of *Calanus* would extend until August—September. Similar conditions were found by Bigelow in the Gulf of Maine (Bigelow 26). Farran (27) has no such secondary maximum, since the number of *Calanus* decreases somewhat evenly from April to September. In those waters the maximum of peridinians also occurs immediately after that of the diatoms (Johnstone, Scott and Chadwick 24).

Fjord.

In 1927 the conditions in Romsdalsfjord were as shewn in the following table:

Table 4.

Year	Date	St. A.	St. Ffj.	St. Rfj.
1927	22/III	2268	1648	6719
	21/VI	2447	4390	4655
	11/VIII		5226	2376

It will be seen from this table that already as early as March 22 there is a relatively large number present at the innermost Station. The number decreases outwards as was the case in the line Station A—Station E early in March. There is a slightly higher number at Station A than at Station Ffj. The value at Station A, however, agrees quite well for the two figures at the same station at the beginning and end of March, which are given in the previous table. Three months later there is a slight decrease at Station Rfj. which continued until August 11th, whilst at Station Ffj. there was an increase during the same period.

In comparison with the conditions on the bank the figures from the fjord are very constant, which is explained by the circumstance that the stock is of a local character, belonging to the fjord and free from the disturbances which an outside invasion would cause. The table appears to shew a slow displacement from the inner part of the fjord to the middle and deeper part. Otherwise the time between the various observations is too long for us to draw extensive conclusions simply upon the number of *Calanus* present.

Outside the Bank.

The results from the long cruises to sea from Möre and for the purposes of comparison those from the "Michael Sars" expedition of 1924 are shewn in Table 5. This is arranged in such a way that the stations with approximately the same hydrographical conditions and situation are placed under each other in the same column. The figures for the various years are not quite capable of comparison, since the hauls were taken with the same kind of net, but at varying depths. In 1924 the depths were from 300—0 metres except at the Stations 10, 11 and 12, where hauls from the depths 100—50 metres are lacking. Thus the values for these three Stations are somewhat too small. In 1925 the depths are from 100—0 metres at Stations 26, 27 and 28. Station 25 and the Stations in 1926 and 1927 were all taken from 200—0 metres. Moreover the dates of the cruises vary.

Table 5. Total Number of *Calanus finmarchius* in the longer Cruises.

1924 11-13/VII	10082		21561	21872	40379	1167	5056	23219
1925 17/VIII				5285	13468	5895	8672	
1926 10-11/VI		23850	53300	47925	34456	9018	4577	13568
1927 31/VII 1/VIII	2856		14034		5304	14144	2572	5974

In order to compare the values with the positions of the Stations in Fig. 3, I here give a key to the above table.

1924	St. 13	..	St. 12	St. 11	St. 10	St. 9	St. 8	St. 7
1925	..	..	..	- 25	- 26	- 27	- 28	..
1926	..	St. 77	- 76	- 75	- 74	- 73	- 72	- 71
1927	- 143	..	- 142	..	- 141	- 140	- 139	- 138

In 1924, July 11th—13th there were large quantities of *Calanus* at the edge of Tampen (St. 7), diminishing to one-twentieth part in the central portion of the Gulf Stream (St. 9). At the next station, St. 10, which also lies on the North West side of the warm salt stream, there are still larger numbers than at St. 7, but from thence and north-westwards the number decreases to 10,082 at St. 13 direct north of the Færoes. Of the other stations situated somewhat near to Norway Stations 5 and 6

are especially interesting for that year. Station 5, which is situated at the edge to the north west of Statt, is very rich, with over 32,000 specimens, whilst St. 6 which lies in the deep channel between St. 5 and Tampen is poor, viz. 4,700 specimens. The hydrographical conditions at these two stations are very much alike, both lying in water of Atlantic origin.

In 1925 on August 17th, St. 27, which lies nearest to the axis of the Gulf Stream, was poorer than the stations on both sides. Otherwise the difference in numbers between the stations is not so great, nor is there a question of such large figures as in the more southern line of stations taken one month earlier in 1924.

The stations taken from June 10th to 11th, 1926 are those which shew the greatest likeness to the "Michael Sars" stations. There are relatively many *Calanus* at the innermost station on the Storeggen, but the number decreases up to the two next stations, Nos. 72 and 73, which hydrographically are situated in the midst of the Gulf Stream. Station 74, again, is far richer and from thence the number increases out to St. 76, which has the largest value of the cruise, viz. 53,300 specimens. At the outermost Station, again, the number is smaller.

In 1927 the conditions were not so simple. The stations were taken $^{31}/_{7}$—$^{1}/_{8}$. At Storeggen a somewhat large number of *Calanus* was found which diminishes to less than one-half at the next station. The third station (Station 140) on the contrary had again a relatively large increase in number. As that station is situated in the central part of the Gulf Stream, this does not appear to be in accordance with the experience of the other years but, as will be seen in the next chapter, it may be explained by the fact that the stock consists chiefly of nauplii and copepodite stages, which are probably bound to the upper layers, where at that station we have coastal water of less than 34 $^{0}/_{00}$ salinity. This circumstance, even though to a small degree, also played a part at St. 73 in 1926. From St. 140 the numbers decreased to St. 141, increased at St. 142 and again decreased at St. 143, which also, apart from St. 140, is, on the whole, in accordance with the results from earlier cruises. Thus the result of the above is: that in this region in the years 1924—1927 there is a maximum of *Calanus finmarchicus* along the edges of the coastal banks, a minimum in the central part of the Gulf Stream and a maximum along the border layers of the Gulf Stream towards the Norwegian Sea. The conditions are clearer in June and July than in August.

Without wishing to generalise in this respect, I have drawn on the map Fig. 3 the border lines of the region in the Gulf Stream which has a number of *Calanus* less than 10,000 in hauls made from 200—0 metres (300—0). It will be seen from this how closely the region for a minimum occurrence of *Calanus* follows what we are accustomed to regard as the general course of the Gulf Stream along the West Coast of Norway. It does not appear to be reasonable to assume that conditions in the month of May were essentially different. This view appears in part to be at variance with the following statement by Damas and Koefoed (07 p. 388). They

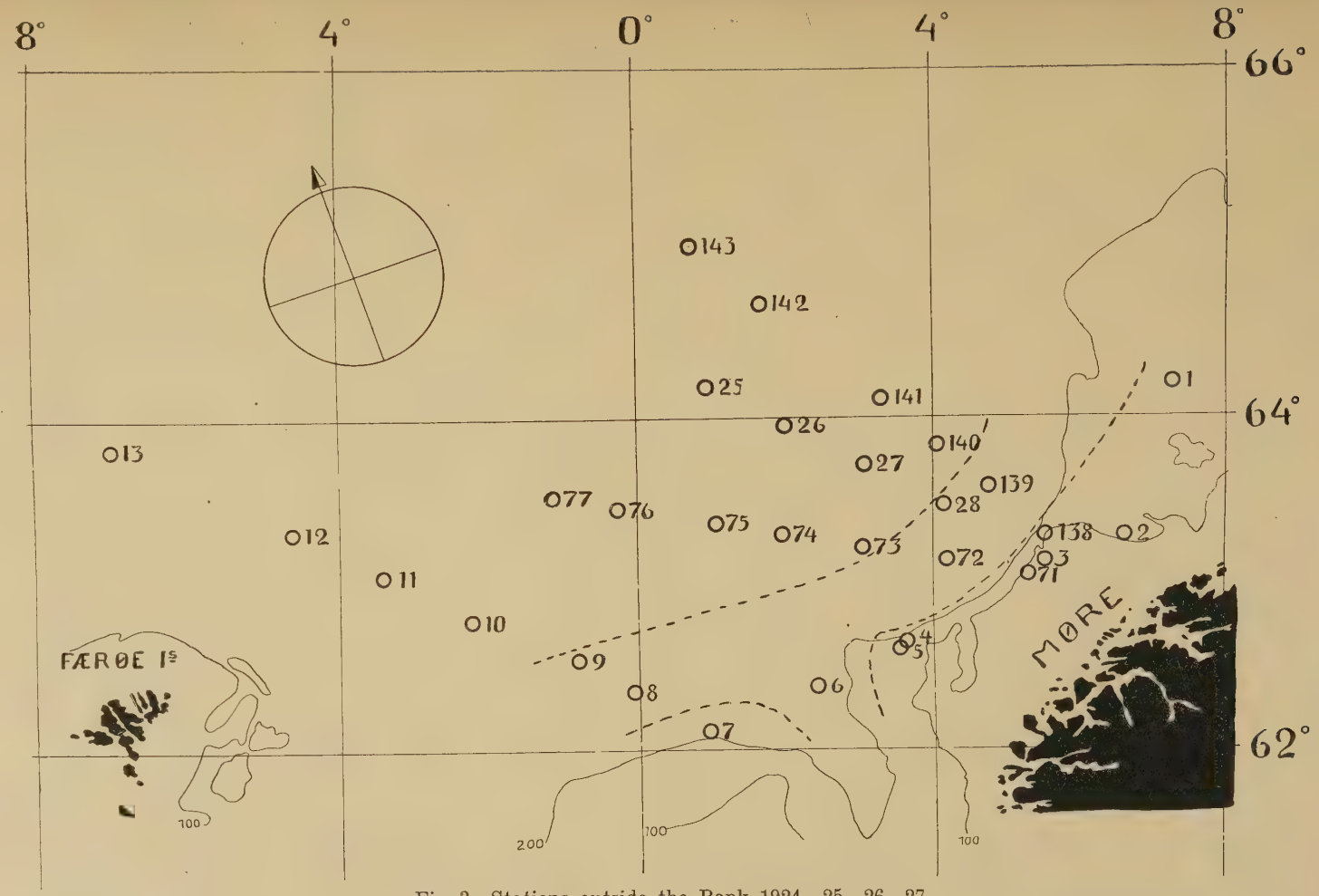

Fig. 3. Stations outside the Bank 1924—25—26—27.

there say regarding *Calanus finmarchicus:* "A une même latitude le nombre d'individus existant sous chaque mètre de superficie, atteint son maximum au niveau du talus continental, c'est-à-dire dans l'axe du Gulfstream; ce nombre diminue, d'une part, vers le plein océan, d'autre part, vers la côte". The discrepancy partly consists of the view of the situation of the axis of the Gulf Stream, which (according to a statement made by Dr. MARTENS) I consider to lie, e. g. at Möre about 100 miles from land, i. e. 50 miles outside the edge. I cannot see from HELLAND-HANSEN and NANSEN's work (09) that in 1904 (May) the Gulf Stream had any essentially different position off Möre than it has had the last three years. The discrepancy also partly consists in the view of the said authors regarding a maximum on the edges with decreasing numbers on both sides. In support of this they give (page 389) a map from May 1904, where the southernmost line of stations from Tampen in a north-westerly direction coincides to some extent with the stations of "Michael Sars" 1924. The figure values comprise only copepodite stages and adult specimens, since it is recorded that there was a superfluity of larvæ at all stations in the said line. The station nearest to Tampen has a maximum number and that station has very much the same situation as our St. 7 1924. From thence to the next station in the north west there is a distance of about 150 miles, whilst with "Michael Sars" 1924 there were taken two stations at the same distance, Nos. 8 and 9, which exactly shew the minimum number of *Calanus* in this line. The material of DAMAS and KOEFOED thus does not appear to offer any adequate argument against a minimum in the central part of the Gulf Stream.

Variations in the Proportions between the various Stages of Development of Calanus finmarchicus.

The Bank.

In order to form a general view of the numerical distribution of the stages of development at each station in each cruise I have drawn "stock curves" for 1926 and 1927 for each station (Figs. 4 and 5). For 1925 when the continuity was less satisfactory, I have not considered this necessary, but I have given the result in tabular form (Table 6). The values shewn both in table 6 and figures 4 and 5 are the total numbers of *Calanus finmarchicus* caught in the vertical hauls which were made at each station.

1925.

It appears from this table that at the end of May of that year there were a few nauplii at St. E only. Copepodites of stage I were lacking at all stations, stage II was to be found only at the outermost stations and stage III at the two outermost stations. Stage IV, which at station E was found in larger numbers than any other stage, was also present at all the other stations but in an absolutely as well as relatively decreasing number from St. E inwards. Stage V was the most common

Table 6. Number of each Stage at the Stations in 1925.

		St. E.	St. D.	St. C.	St. B.	St. A.
	♂	..	..	414	1820	231
	♀	..	663	1449	3640	616
	V	2272	8083	16974	29575	1848
26—28	IV	3976	2120	1035	385	462
V.	III	2840	133	..	..	..
	II	1136	..	..	..	..
	I	..	..	..	..	..
	N.	568	..	..	..	..
	♂	..	..			
	♀	..	396			
	V	449	1188			
22	IV	449	198			
VII.	III	..	396			
	II	449	..			
	I	449	198			
	N.	2694	594			

stage at the four inner stations with a maximum at St. B. At that station was also the maximum of Stage VI ♀ and ♂ found in this line of stations, Stage VI ♂ was lacking at St. D and both sexes were lacking at St. E. In July the situation was altered at the two outer stations, since at St. E there was a maximum of nauplii and a good stock of stages I, II, IV and V. At St. D there was a maximum of Stage V, but also a high percentage of nauplii. In addition there was a quantity of Stage VI ♀, Stages I, III and IV.

1926.

In 1926 (Fig. 4) on the first two cruises, as will appear from the foregoing chapter, there were only small quantities of *Calanus finmarchicus*. On March 16th there were a number of adult animals at the three inner and at the outermost stations, a circumstance which continued until March 26th. Otherwise the curves shew that there was a maximum of nauplii at St. A with a decreasing number of stages I and II. At Stations B and C, and in the second cruise also at St. E there were also a number of nauplii and small copepodite stages, but in considerably smaller quantities than at the inner Station. The great changes in the stock which took place on April 9th at the four outer stations, therefore have the effect of an invasion. There are three different types of stock curves for the third cruise:—

1. At Station A the number of *Calanus* was of the same order of size as on March 26th. The alteration consisted in the fact that the number of nauplii, which were still domin-

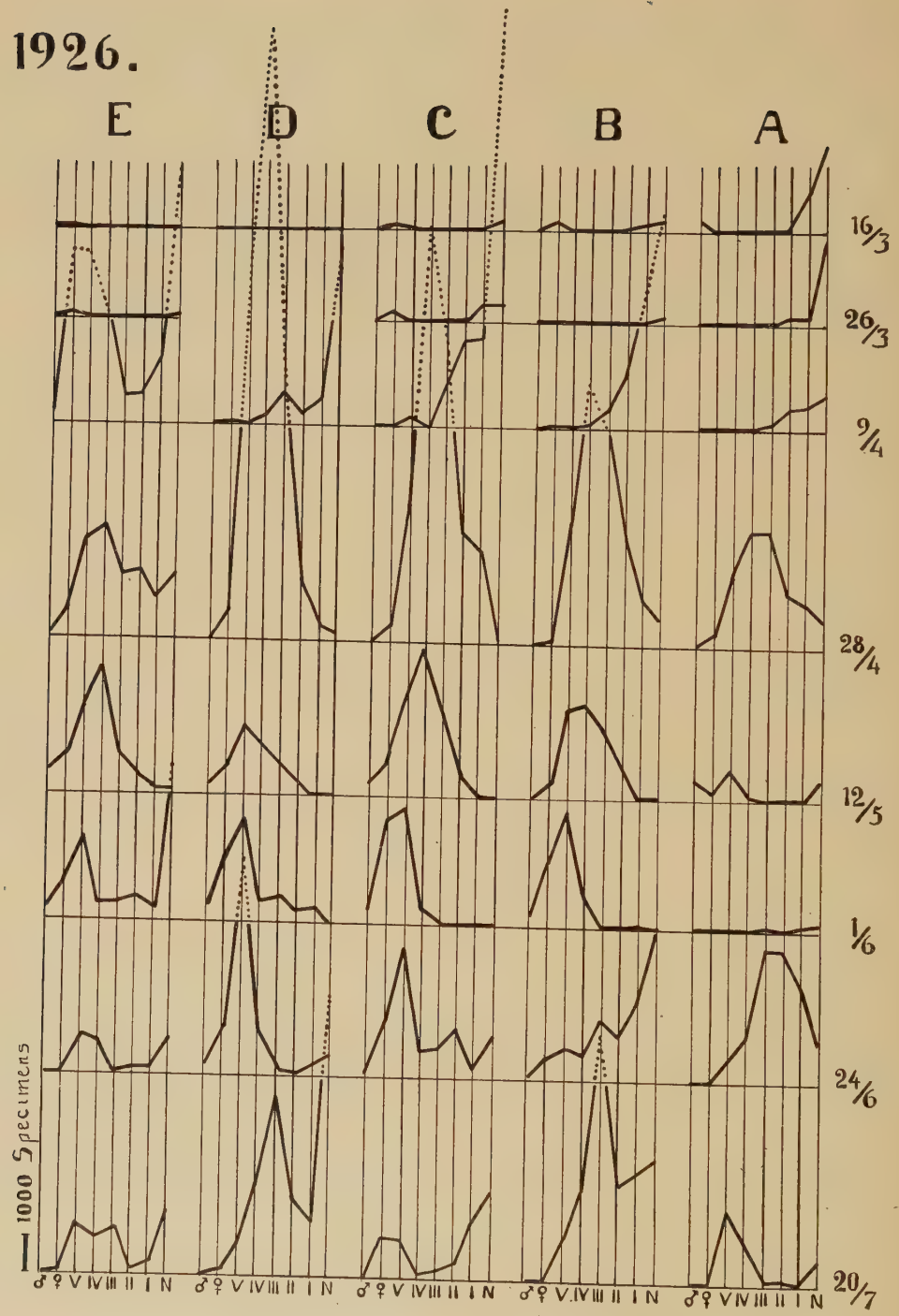

Fig. 4. Stock curves for *Calanus finmarchicus*.

ating had decreased, whilst the number of stages I, II, III and IV had somewhat increased. This circumstance was to be expected as the result of the development of the stock.

2. At Stations B, C and D where the stock had increased 10 to 50 times the former number there was an enormous maximum of nauplii with decreasing values for stages I, II and III. There were only small quantities of stages IV, V and VI.
3. At Station E there was also a maximum of nauplii, and even larger numbers than at Stations B and D, and there were decreasing values for stages I, II and III, but there was, however, also a secondary maximum of stages IV, V, and VI ♀ and smaller quantities of VI ♂. In addition to a stock of smaller stages like that of the inner stations, there was also an invasion of adult and almost adult animals. It is obvious that the situation at Stations B, C, D and E on April 9th had no connection with the situation in the foregoing cruise, but as we shall see later on the change can be explained in a fully satisfactory way by the current conditions.

On April 28th the curves of stock shewed a further development. Stage IV was present in maximum numbers at all stations. There were still a few nauplii at the middle stations and somewhat more at Stations A, B and E. The curves shew that there was a decreasing figure for the stages on both sides of Stage IV. At Station A the number of Stage III was almost the same as for Stage IV, but the predominance of the latter stage became more and more marked through Stations B, C and D. At St. E again, the conditions were more like those which we found at the inner Station. The number of Stage IV noted at St. D was the greatest number of any single stage noted on the bank that year.

On the 12th May the numbers of *Calanus* had decreased over the whole bank and Stages IV or V predominated in number. The curves for the three middle stations shew that there was a displacement towards the adult stages whilst nauplii and Stage I were lacking. On the other hand, at Stations A and E there were still a few nauplii and Stage I.

On the 1st June the number of *Calanus* had greatly decreased at the inner station and the few remaining belonged mostly to the lower stages from nauplii to Stage III. At Stations B, C and D Stages V was predominant and displacement towards adult animals which we noted in the previous cruise had become even more marked. At the outermost station the situation reminded us of that which we had on April 9th, although on a smaller scale. There was a maximum of nauplii, relatively few of Stages I to IV and a secondary maximum of Stage V with many VI ♀ and ♂.

On June 24th again there were many *Calanus* at Station A. The curve which is reminiscent of that for Station A on April 28th, shews that there was a maximum of Stages II and III, relatively many of Stage I and nauplii, somewhat fewer of Stages IV and V whilst stages VI ♀ and ♂ were lacking. At Station B there was a maximum of nauplii with decreasing values through Stages I to VI ♂. There was, however, an indication of a secondary maximum of Stage III. At Station C there was still a maximum of Stage V, whilst all other stages were represented in some-

what varying numbers. The curve for Station D was more regular there being a maximum of Stage V decreasing upwards and downwards, with a slight increase in nauplii and Stage I. At the outermost Station Stage V continued to be predominant. There were also many of Stage IV and nauplii, but few or none of the other stages.

In the last cruise on July 20th at the inner station there was a maximum of Stage V, many of Stage IV, a number of nauplii, but otherwise few or none of the other stages. At Station B there was a maximum of Stage III, a secondary maximum of nauplii, and decreasing numbers of Stages I, II, IV and V. There were similar conditions at Station D with the difference that nauplii formed the primary maximum and Stage III, the secondary. At Station C nauplii dominated and the numbers decreased from Stages I to IV, whilst Stages V and VI ♀ formed a new top on the curve. At Station E there were also the most nauplii, but in addition there were many of Stages II, IV and V. The other stages were present in smaller numbers. The many nauplii and small stages, especially Stage III, indicate a later maximum of larger stages, and at the same time the relatively large stock of animals in Stages V and VI ♀ gives signs that spawning will continue for some time onwards.

1927.

In 1927 (Fig. 5) the situation at the beginning of March was exactly the same as in the middle of March the previous year. There were small quantities of adult animals, and to some extent of Stages IV and V at most of the stations, whilst there were relatively large numbers of nauplii at Station A and decreasing values outwards at Stations B, C and D. In addition at Stations A and D there were some few specimens of Stage I.

The other stages were lacking in the whole line of stations.

The great increase in numbers occurred as mentioned above as early as the end of March of that year, and the increase was greatest somewhat farther in at St. B, whilst St. A unlike in the previous year shewed an enormous increase in numbers. Nauplii predominated at all stations, with decreasing value for the stages from I and upwards. The development was most advanced in the innermost parts, there being a very considerable number of Stage IV. There were still some quantities of Stage V and VI ♀ and ♂ at all stations. At the outermost station unlike the previous year, there was no noticeable invasion of large, in part adult animals, at the same time as this large number of nauplii and younger stages of development.

In the third cruise Stage IV was predominant at Stations A, B and C. The curve was oblique towards Stage VI ♀ at St. A, whilst for Stations B and C it was very symmetrical with decreasing values for the stages larger and smaller than Stage IV. There were few or no nauplii and Stage I. At Station D there was a maximum of Stage V with a symmetrical decrease to Stage VI ♀ and ♂ and Stage IV and III. There were few of Stage II, but somewhat more of Stage I and nauplii.

Fig. 5. Stock curves for *Calanus finmarchicus*.

At the outermost station Stage VI ♀ was predominant with many ♂ and Stage V There were few of the other copepodite stages, but a number of nauplii. This marked predominance of adult animals has many points of similarity with the invasion previously mentioned on April 9th 1926 at the same place.

On June 1st at the three inner stations there was a maximum of Stage V with many VI ♀ and ♂ and few or none of the other stages. Like the previous year there were most nauplii at Station E and decreasing numbers of the rising stages. There were none of Stage V, but a number of VI ♀.

In the line of stations on June 29th there were many nauplii at St. A, fewer of Stages I and II, none of III and IV, but a number of Stages V and of VI ♀. At Stations B and C Stage V predominated, and in addition a number of nauplii at St. B. Stages IV and V predominated right up to the two outer stations, with few or none of the other stages.

In that year on the 31st July the last cruise shewed the most nauplii at all stations except E, where there was a maximum of Stage V. Nauplii predominated especially at Stations C and D. The number of the other stages decreased upwards, but like that at the last cruise in 1926 not evenly, there being small secondary maxima of Stages II, III or IV. At St. E in addition to Stage V there were a number of Stage II and nauplii.

The result of the three years' investigations (Table 6, Figs. 4 and 5) can be summed up in the following way.

At the beginning of March over the whole bank there is a small, somewhat even stock of *Calanus finmarchicus*, adult specimens and in part older copepodites. Spawning probably began in February, innermost at St. A, there being a maximum number of nauplii decreasing outwards. At the end of March (1927), or at the beginning of April (1926) a change occurs in these conditions, for in the line St. A to St. E there occur large numbers of nauplii and to some extent younger copepodite stages. The maximum of this stock lay farther out on the bank in 1926 than in 1927, at Stations C and B respectively. This is explained satisfactorily by the marked compression of coastal water at St. B in the last year. At the end of April to the beginning of May the nauplii and the smaller copepodite stages had almost disappeared from the bank, whilst there was a distinct maximum of the larger stages such as IV and V. In 1926 the maximum number of these lay at St. D, whilst in 1927 it was at St. B. In the last year the mass of coastal water on the 3rd May was still at St. B, whilst on the 28th April 1926 the coastal water was shallower there and extended considerably farther out to sea.

At St. A this invasion of nauplii and later of older copepodite stages in 1926 was not noticeable, but it was very marked there in 1927.

At the same time (1926) or somewhat later (1927) as the invasion of this stock which appears to live in the current of coastal water, there occurred an invasion of larger, and in part adult animals out at Storeggen at St. E. That there

are two populations would appear from the stock curve for St. E, April 9th 1926. I shall, however, return to a further proof of this contention in the discussion on measurements of length. In the middle of May there are still fewer nauplii and smaller copepodite stages in the samples, and at the end of May to the beginning of July, as regards the middle stations there are scarcely any *Calanus* smaller than Stages IV and V. On the edge the conditions were somewhat different since in addition to the larger stages there was a distinct maximum of nauplii. The year (1927) when St. A was rich in individuals and appeared to belong to the coastal water there were no nauplii as early as $^1/_6$, whilst in the previous year, when St. A was very poor there was a slight maximum of nauplii also at this Station. At the end of June in the inner stations there was a maximum of smaller stages and nauplii. This appeared to occur somewhat later in 1927 than in 1926. At the end of June there was a maximum of stages IV and V, and some nauplii at the outer stations.

At the end of July the conditions were more mixed, since on the whole the maximum of nauplii and smaller stages (Stage III) existed, but there were also many and in some cases a maximum of larger stages V and VI ♀ (St. E 1927, St. A and C 1926).

Although I am aware that the conditions at St. E and to some extent, at St. A differ essentially from those of the other stations, I have nevertheless drawn tables and curves for 1926 and 1927 which illustrate the changes from one cruise to the other. In the tables the number for each stage has been summed up in the whole line of stations, with the results shewn in tables 7 and 8.

Table 7. Number of each Stage the various Dates in 1926.

Cruise	16-18/III	26-27/III	9-10/IV	28-29/IV	12/V	1-2/VI	24-25/VI	20/VII
♂	335	77	319	203	1819	1206	403	8
♀	400	456	5245	3032	3445	7506	3415	1382
V	..	19	5218	22601	10008	11721	11983	6539
IV	..	145	3698	42412	11667	2259	4744	7631
III	..	133	3843	26221	6518	1328	6261	13481
II	244	346	5813	11680	2478	983	6449	5363
I	1326	769	9322	7198	198	1089	5508	6500
N.	2902	3136	31489	3760	618	4686	7644	15568

The curves in Figures 6 and 7 have been drawn on the basis of the above tables, the intervals between the cruises being placed upon the axis of the abscisses and as ordinates the total figures for each stage which will be found in the tables. The scale to the left of the figures gives the number in thousands. Only the curves for Stage VI ♀, III and nauplii are included in the figures with a view to a general

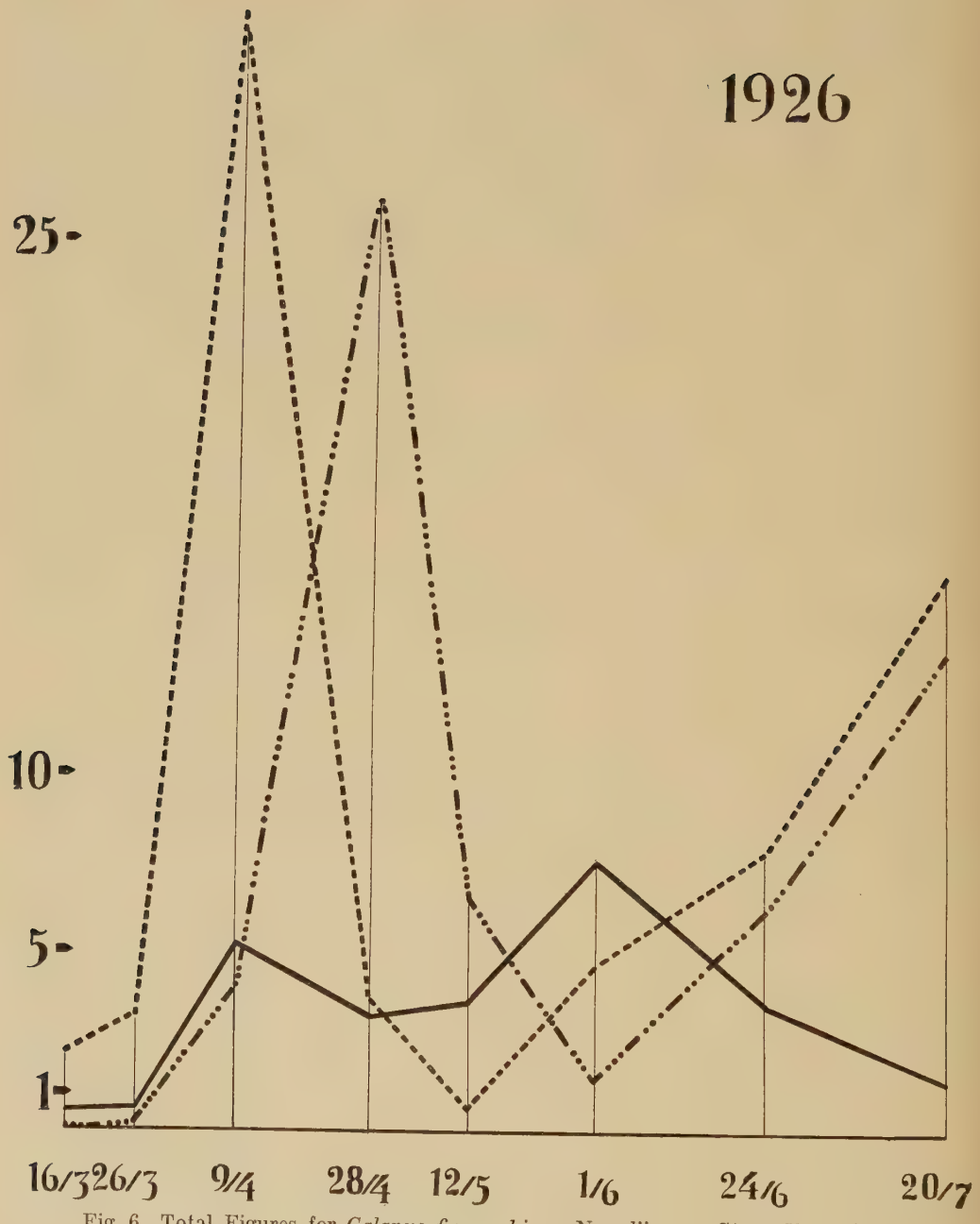

Fig. 6. Total Figures for *Calanus finmarchicus*, Nauplii - - -, Stage III —·—·— and Stage VI ♀ ——.

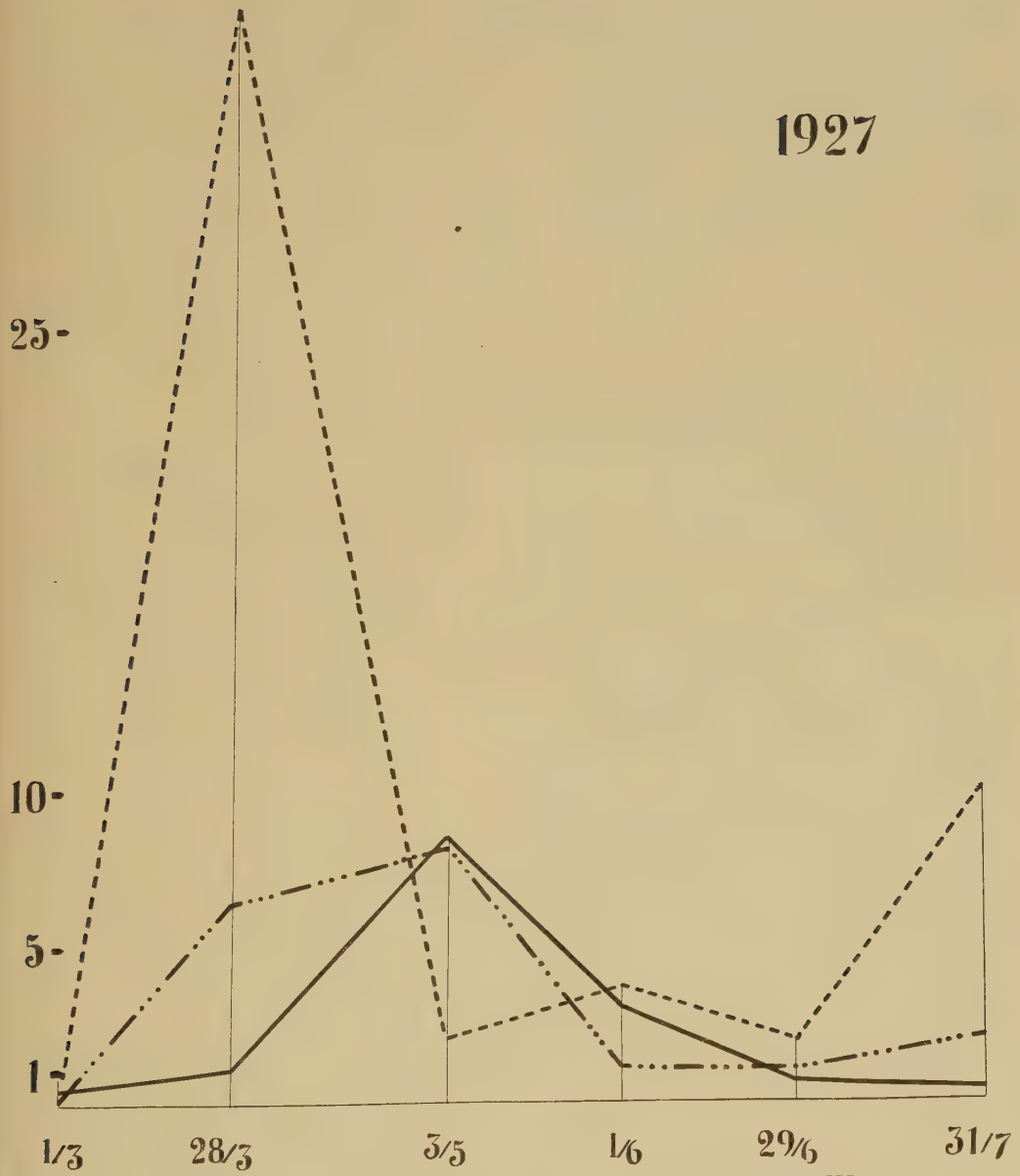

Fig. 7. Total Figures for *Calanus finmarchicus*, Nauplii - - -, Stage III —·—·— and Stage VI ♀ ——.

Table 8. Number of each Stage the various Dates in 1927.

Cruise	1-2/III	28-29/III	3-4/V	1/VI	29/VI	31/VII
♂.....	53	1122	1800	302	..	41
♀.....	323	1103	8693	3222	514	274
V	187	1486	15483	5849	12279	4952
IV.....	143	6419	23428	570	11811	2052
III.....	..	6498	8347	1085	1041	1886
II.....	..	12936	1799	695	613	3419
I.....	40	14645	650	1133	986	3410
N.....	929	36221	2220	3833	2120	10207

survey. Moreover, it will be seen from the tables that the figures for the other stages synchronize well with the three mentioned above.

The curves for 1926 (Fig. 6) shew that from a minimum in March a maximum of nauplii develops in quite a short time on April 9th, followed by a maximum of the copepodite Stage III on April 28th and of Stage VI ♀ on June 1st. The curves for nauplii and Stage III rise throughout the last cruises, although it cannot be stated whether the maximum for any of them is reached on July 20th. These curves have not such a steep ascent as in the months of March and April, which is explained by the circumstance that spawning in May and June is more scattered and is not of such a spontaneous character as the first spawning in February—March. There is a minimum of nauplii on May 12th and of Stage III on June 1st. There is a slight maximum on the curve of Stage VI ♀, corresponding to the large invasion of that stage on the Storeggen April 9th.

The curves for 1927 (Fig. 7) suffer from the circumstance that the cruises were not made so close upon each other as in the previous year, but nevertheless we obtain on the whole the same picture for both years.

We have a vigorous maximum of nauplii on March 28th. The curve for Stage III is of such a quality that it must be assumed that the maximum for that stage lies in the time between March 28th and May 3rd, as observations are lacking. There is a minimum of nauplii on May 3rd, a slight increase on June 1st, a new minimum on June 29th rising towards a maximum on July 31st. This corresponds completely to the circumstance that in 1927 there were many nauplii at St. E on June 1st, whilst at the other Stations there were no appreciable numbers before July 31st. The curve for Stage III therefore also only indicates a rise on July 31st. On May 3rd there was a large maximum on Stage VI ♀, over one-half of which was due to an invasion at St. E. The maximum of VI ♀ for the other stations is probably found at the end of May, but observations from that time are lacking. As it is now, the contributions of the other stations to this curve are completely overshadowed by the adult females at St. E on May 3rd.

The Fjord.

In 1927 the distribution of the stages of *Calanus finmarchicus* was, as will be seen from table 9.

We will here take the reservation as regards nauplii that quite a high percentage of them presumably belonged to *Calanus hyperboreus* (Kröyer) of which species there is a very considerable stock especially at the innermost stations.

Mr. Jacob D. Sømme has kindly gone through one of my samples from the Fjord and informs me that of 218 determined nauplii 46 belonged to *Calanus hyperboreus* and 172 to *Calanus finmarchicus*.

On March 22nd there was a maximum of nauplii at all three stations and a decreasing number of the rising stages. At the two inner stations there is a minimum of Stage IV and a slight increase of Stages V and VI ♀. All stages from nauplii up to and including Stage III were in the layers above 50 metres, whilst the larger stages were in the deeper layers. This would appear to support the idea that the stages up to and including III belong to a new generation. The figures decrease from the inner part of the fjord outwards. This condition compared with the outward current in the surface layers shews that spawning must first have begun innermost, and perhaps was most vigorous there, although it cannot be said whether the maximum of nauplii is past at any of the stations. Three months later Stage V predominated at the outermost station together with Stage VI ♀. There were also a number of nauplii, whilst the intermediate stages were entirely lacking, except at St. A where there were a few specimens of Stages I and IV. Apart from St. A where a

Table 9. Number of each Stage of *Calanus finmarchicus* at the Stations in the Fjord 1927.

		St. A.	St. Ffj.	St. Rfj.
22/III	♂	27	20	13
	♀	56	59	20
	V	57	43	101
	IV	71	28	28
	III	327	78	217
	II	338	122	302
	I	243	190	389
	N.	1149	1310	5649
21/IV	♂	194	7	15
	♀	829	122	206
	V	932	3549	2964
	IV	65	..	151
	III	..	..	..
	II	..	..	..
	I	79	..	..
	N.	347	712	1318
11/VIII	♂		47	..
	♀		141	..
	V		4187	2128
	IV		235	38
	III		282	70
	II		99	..
	I		94	..
	N.		141	140

mixture of animals from without is possible, and it may be probable, there is such a pure condition at the two inner stations that the number of *Calanus*, taking into consideration a natural dissemation of the stock, is of the same order of size as in the previous cruise, so that the stock in the fjord may be regarded as of local origin. On Aug. 11th there was also a maximum of Stage V in the fjord, but at the outer Station all stages, although in smaller quantities, were represented. This indicates that there is also spawning in the fjord during the summer, but in any case judging from the existing material it is insignificant. It is impossible to say at present whether it may be more vigorous later or whether it is different in other years.

Outside the Bank, 1924.

The distribution of stages of *Calanus* in the line Tampen-Færoes on "Michael Sars" in 1924 will appear from Table 10.

Table 10. Number of each Stage of *Calanus finmarchicus* in the Line Tampen—Færoes 11—13/VII 1924.

	St. 13	St. 12	St. 11	St. 10	St. 9	St. 8	St. 7
♂	..	..	..	..	..	..	..
♀	98	..	58	778	..	..	1495
V	2668	8664	2384	34427	437	3634	18136
IV	7316	11529	14312	4396	146	790	3588
III	..	912	3094	..	..	..	..
II	..	456	1518	..	146	..	..
I	..	..	..	..	73	158	..
N.	..	..	506	778	365	474	..

There were only a few nauplii and smaller copepodite stages in the whole line, and only at the middlemost stations where they were found in the upper layers above 50 metres. Stage V predominated at Stations 7, 8, 9 and 10, but otherwise Stage IV predominated. At Stations 7 and 13 there were no stages except IV, V and VI ♀ There was a striking likeness between the distribution of stages at Stations 7 and 10 on each side of the axis of the Gulf Stream. This may be so explained that there must be an intimate connection between them, but the poor and intermediate stations, where the distribution of stages is somewhat different, may also justify the assumption that the conditions at Stations 7 and 10 are convergence phenomena. Station 13 is hydrographically situated in a tongue of Gulf Stream water, which enters the Norwegian sea to the north of the Faroes (See Störmer 27, Fig. 5). The distribution of stages there was also very regular since there were many of Stage IV, fewer of Stage V and very few of Stage VI ♀. Stations 11 and 12 which

are situated between the above mentioned tongue of the Atlantic and the Gulf Stream, had also a maximum of Stage IV. At Station 12 there were many of Stage V and a number of Stage III and II, whilst at Station 11 there was displacement towards the smaller stages, there being more of Stages III and II than of V and IV, and in addition there were a few nauplii. At Stations 5 and 6, which are situated near Norway, the situation was exactly like that at St. 7, only with a difference in numbers mentioned above.

1925.

In the line of stations from Möre on Aug. 17th 1925 the distribution of stages was that shewn in Table 11 and was essentially different from that in the "Michael Sars" line the nauplii, apart from St. 25, being in the majority. There were decreasing numbers of the latter from St. 26 towards the land to St. 28.

Table 11. Number of each Stage of *Calanus finmarchicus* in the Line of Stations over the Gulf Stream from Möre $^{17}/_{8}$ 1925.

	St. 25	St. 26	St. 27	St. 28
♂	..	..	..	..
♀.....	903	...	..	..
V	3612	962	..	1626
IV	512	962	..	1084
III.....	129	2405	1572	2168
II.....	129	1924	393	542
I.....	..	962	786	542
N.	..	6253	3144	2710

At the three inner stations there was a slight secondary maximum of Stage II and at St. 27 there were none of the larger stages, whilst at Stations 26 and 28 there were a number of Stage V and VI ♀. At the outer station there was a maximum of Stage V, a number of VI ♀ and Stage IV and a few of Stage III and II. I would here draw attention to the fact that at St. 27 there were only found stages which in general are regarded as bound to the upper layers of water, where at that station the water was of a salinity less than 35 $^{0}/_{00}$. However, as previously mentioned, the hauls at the three inner stations were not taken deeper than 100 metres, and therefore the number of the larger stages at least cannot be quite compared with the conditions at the outer station.

1926.

In 1926, however, all hauls were taken from 200—0 metres and the cruise which was taken from the 10th—11th June was more complete, as it extends from Storeggen at Station E right over the Gulf Stream.

As will be seen from Table 12 there were two areas of nauplii in this line one maximum at the outermost station and a decreasing number inwards towards Stations 76 and 75. There were further a number of nauplii at the innermost Station 71 somewhat fewer at Station 72 and again a number at Station 73, which from a hydrographical point of view was of the same type as Station 71 in the surface

Table 12. Number of each Stage of *Calanus finmarchicus* in the Line of Stations over the Gulf Stream from Möre June 10th—11th 1926.

	St. 77	St. 76	St. 75	St. 74	St. 73	St. 72	St. 71
♂	..	..	..	..	..	..	..
♀	612	..	1350	..	..	199	1272
V	4892	17056	3375	1888	2004	1990	4240
IV	6115	24518	4725	9440	2505	1393	3392
III	1223	8528	23625	13688	501	597	1696
II	612	2132	8100	8968	1503	..	..
I	1835	..	6075	472	501	199	848
N	8561	1066	675	..	2004	199	2120

layers since there was a layer of fresh coastal water which at Station 72 was partly separated from the other layers of coastal water.

As previously mentioned there was a distinct difference in numbers between the four outer and three inner stations. There was a similar difference in the distribution of stages at the two groups of stations. At the three inner stations, 71, 72 and 73, there was a maximum of Stages IV and V, but the predominancy over other stages such as nauplii, in part Stages II and III and over VI ♀ (Station 71) was small. At Stations 74 and 75, however, stage III predominated over all the others, the figures for the latter steadily decreasing from stage III upwards and downwards. The predominancy was marked especially at Station 75, in that Stage III there amounted to about one-half the number of all *Calanus* at the station. At Station 76 it was Stage IV, closely followed by Stage V which predominated and at Station 77 there were similar conditions, the number of nauplii, however, exceeding the number of Stage IV.

1927.

In 1927 the cruise from Möre was taken from July 31st to August 1st. As shewn in Table 13 Stage V predominated at all stations.

There were few of the other stages at the three outermost stations, whilst at the three innermost stations there was a small but rather regular stock of nauplii and other stages of copepodite.

The majority of the nauplii and small stages of copepodite and of Stage VI ♀ were found at Station 140, but in similarity to the Station 73 in 1926 there was a quantity of coastal water in the upper layers at that station. The distribution of stages, however, is such that it may be said that the three outer and the three inner stations belong to different groups, the large number of Stage V at Station 140 possibly indicating that the conditions there were very mixed.

As a result of the distribution of stages in the four longer cruises which have

Table 13. Number of each Stage of *Calanus finmarchicus* in the Line of Stations over the Gulf Stream from Möre July 31st to August 1st 1927.

	St. 143	St. 142	St. 141	St. 140	St. 139	St. 138
♂	..	..	..	..	..	..
♀.....	526	..	426	774	..	59
V	1674	13440	4580	7066	1292	4112
IV	164	362	..	145	44	196
III.....	..	..	..	194	132	59
II.....	164	..	..	533	132	527
I.....	..	181	..	1746	220	156
N.	328	51	298	3686	752	567

been dealt with separately above, we may make the following points: As regards the distribution and number of stages the conditions in June and July at the outside of the Gulf Stream are of a nature strongly resembling the conditions on the bank in April and May, in that Stage III and later on IV and V predominate. All conditions at the inner stations are in more intimate connection with those on the bank. There are features indicating that the area at the outer border of the Gulf Stream and between the latter and the Atlantic Stream which runs North of the Færoes is an area of breeding (Damas 05), and also that spawning takes place at certain times in the coastal water along the coast of Norway and in the masses of water which come from the same. In August the masses are considerably less and the conditions on the whole are more like those of the summer on the bank. The two areas appear to merge into each other.

On the basis of these conditions at Möre and by parallelising the results from the Phyto-plankton investigations (Gran, this volume) we can form the following picture of the occurrence, spawning and development of *Calanus finmarchicus* off the west coast of Norway.

In similarity with the results arrived at by Gran we must also in the case of copepods assume that the conditions in the coastal water and at the Storeggen are two different phenomena.

Calanus finmarchicus in the local coast plankton begins its development at Möre by spawning in the fjord and skerries by the animals which have remained here throughout the winter. This spawning is completely overshadowed in March—April by nauplii and younger copepodite stages which are spawned earlier and farther south along the coast of Norway and carried into our observation line by the Baltic Stream. Later on there occurs successively the various stages of copepodites until in May and June we have Stages IV, V and VI. These latter adult

individuals then spawn in the Möre region and the cycle is repeated. On account of the continuity between our observations we must thus assume that spawning takes place continuously along the coast of Norway. We are inclined to believe that spawning like the development of phytoplankton begins farther south and that the action proceeds northwards. In this case we have in the Möre area a time condensed picture of the development of *Calanus*. In 1926 there were about 7 weeks between the maximum of nauplii and the maximum of Stage VI ♀. With an embryonal development of 3 to 4 weeks (Lebour 16) *Calanus finmarchicus* off our west coast thus requires almost three months for its life's cycle. This does not appear to be unreasonable when compared with Crawshay's results, namely about two months (Lebour 16).

With the incomplete data concerning the Baltic Stream which is at present at our disposal, nothing certain can be concluded, but at all events, that which is sketched above assumes that in the winter months there is a comparatively rich stock of *Calanus finmarchicus* in the outer Skagerak and the North Sea. According to Aurivillius (98) and Farran (11) *Calanus* is common in the Skagerak the whole year round, but according to the latter the stock is also dependent upon invasion from the Shetland Bank in the North.

The large stock of *Calanus finmarchicus* off the Storeggen in April and May occurs like the phyto-plankton first of all in the Gulf Stream's rich border layer, from which it then spreads and mixes with the stock from the coastal water. In the case of *Calanus* it is conceivable that there are several possibilities for this immigration. The individuals may be spawned off Shetland and to the West and may have completed their development to Stages IV, V and VI on their way to Möre. With a speed in the Gulf Stream of about 14 nautical miles per 24 hours (Helland-Hansen and Nansen, 09) this would approximately agree as to time and direction. It is also conceivable that individuals which have spent the winter in the deeper parts of the Norwegian Sea wander up into the favourable masses of water along the whole of the Storeggen from Statt to Nordmöre. These two explanations appear to be most acceptable, but, with the existing material, it is impossible to say whether there are several solutions and which is the most probable.

Later on in the summer the two communities of plankton, as mentioned above, mix together in the coastal water drifting out to sea and partly travelling over the Gulf Stream. There is also here a possibility of communication between the regions on both sides of the Gulf Stream, from the coastal water to the central part of the Norwegian Sea over the Gulf Stream and in the opposite direction under the same.

Longitudinal Variation of Calanus finmarchicus.

It is well known that *Calanus finmarchicus* like other copepods is subject to great variations in length, and that these variations in the first instance are de-

pendent upon the conditions of temperature. It must be assumed that this is generally accepted. (Gran 02, Adler and Jespersen 20, Rzoska 27).

In accordance with previous investigations the measurements of the material from Möre shewed that *Calanus* from a minimum length in February—March grew to a maximum in the Spring months and again decreased to a minimum in the Summer. There was, however, a not inconsiderable difference in length of *Calanus* between the various stations in the cruises and between the two years 1926 and 1927 when the measurements were taken.

The Bank 1926.

The measurements on the bank in 1926 are shewn in the following table:

Table 14. Length in mms. of *Cephalothorax* of *Calanus finmarchicus* Stage V, the Bank 1926.

Date	St. E.	St. D.	St. C.	St. B.	St. A.
18/III	..	..	..	..	2.32*
26/III	2.39*	..	2.14*	..	..
9/IV	2.53	..	..	2.50	..
28/IV	2.54	2.51	2.52	[2.41]	2.65
12/V	..	..	..	..	2.45
1/VI	2,45	..	2.48	..	..
24/VI	..	..	..	..	2.41
20/VII	2.40	..	2.45	..	2.33

* 28/IV.

The first three measurements marked * were calculated from measurements of Stage IV ♀ and the value at Station B $^{28}/_{4}$ is placed in [ ], as this value is undoubtedly too small. The fact is, the measurements there were taken in a sample which on account of other objects was fixed in "Carnoy" which shrivels the animals a good deal. We see from the table that even as late as March 26th the animals were small, whilst on April 9th at the same time as the previously mentioned increasing mass they were considerably larger. There are measurements from all stations on April 28th, and apart from Station A they are uniform. At the latter Station, however, it appears that there are two distinct tops to the curve for measured specimens, so that they are 25 % grouped about a considerable length and 75 % about a smaller one. If these two groups are dealt with separately the lengths are found to be 2.98 and 2.54. There also appear to be at Station A two populations, 75 % of the same order of size as at the other stations and 25 % of larger individuals. The latter are an isolated phenomenon, and there was no parallel to it next year.

The mean error of the medium for all stations is from 0.011 to 0.021 whereby the true mean value has a correction ± 0.033 to ± 0.063. The dispersion is almost the same for all stations, namely about 0.11. This should support the idea that the stock at all stations belongs to the same population. It would appear from the stock curves for that year and the measurements for 1927 that this is not altogether reasonable, and we must therefore possibly regard this agreement in length between Station E and the other stations as a phenomenon of convergence. Later on in the Spring and Summer the lengths decreased, most at Station A and least at Station C. The difference between these two stations on July 20th was so great that the stocks at the two stations cannot be said to be of the same origin. However, we can see from the stock curves for that year (Fig. 4) that a second spawning began at Station A earlier than at any of the other stations. Also the increase in temperature was earliest and most marked at that station.

1927.

In 1927 at the beginning of March the lengths were small and almost of the same size as those estimated for Stage V in March the previous year. Increase in length was noticeable at the inner stations at the end of March and at the beginning of May at Station E. In the cruise $^{3}/_{5}$ the lengths of *Calanus* at the four inner stations were less than at Station E, so much so that the correction, taken into consideration, just touches the upper value at Station D the lower value at Station E. The values are 2.38 ± 0.071 and 2.51 ± 0.063. The maximum lengths for that year were measured on the cruise $^{1}/_{6}$ and subsequently the lengths decreased as in the previous year.

In 1927, to judge by the lengths, there were two different populations on the bank, one at the four inner stations and one at the Storeggen. At the latter the lengths developed in 1927 as in 1926, but the stock at the bank in 1927 was a good deal smaller than in the previous year. The maximum length was measured later in 1927 than in 1926.

The hydrographical conditions for the two years, especially the temperature, were also so different that they may have caused such a difference in length. In order to obtain an idea of the conditions in those two years I have compiled some hydrographical data in Table 15 which may conceivably shew the co-relation in length in the two lines of stations $^{28}/_{4}$ 26 and $^{3}/_{5}$ 27. A priori we must assume that the hydrographical conditions in the same line will not give a particularly good co-relation, since it is presumably the conditions during the whole development which characterise the growth. I have therefore in the table also included the same hydrographical dimensions found at the same place one month before, although I am aware that the masses of water in which the animals lived at that time were far to the South West of our observation line. All our hydrographical data were taken from a depth of 25 metres, since *Calanus*, Stage V, had its maximum extension between 50 and 0 m. The hydrographical data from 1 month before, on the

Table 15. Length in mms of *Cephalothorax* of *Calanus finmarchicus*, Stage V in the Lines of Stations $^{28}/_{4}$ 26 and $^{3}/_{5}$ 27 and the Hydrographical Conditions in the Lines $^{28}/_{4}$, $^{26}/_{3}$ 26 and $^{3}/_{5}$ and $^{28}/_{3}$ 27.

	St. E.	St. D.	St. C.	St. B.	St. A.	Date Year	Depth
L	2.54 2.51	2.51 2.38	2.52 2.34	[2.41] 2.36	2.65 2.40	28/IV 26 3/V 27	25 m.
T°	8.35 7.64	5.50 7.55	4.95 5.34	5.31 4.95	5.00 5.26	28/IV 26 3/V 27	
S ‰	35.23 35.10	33.82 35.01	33.13 32.90	33.17 32.41	33.06 32.83	28/IV 26 3/V 27	
σ_t	27.41 27.43	26.41 27.38	26.22 25.99	26.21 25.66	26.16 25.95	28/IV 26 3/V 27	
O_2	6.46 5.78	6.54 6.35	6.84 7.34	7.04 7.35	7.13 7.46	28/IV 26 3/V 27	
M %	99.1 87.2	95.4 95.6	95.9 103.9	99.5 102.3	100.0 105.2	28/IV 26 3/V 27	
T°	6.27 6.71	.. 6.52	4.06 5.13	4.05 5.07	3.92 5.07	26/III 26 28/III 27	10 m.
S ‰	34.51 34 49.	.. 34.47	33.26 33.08	33.19 33.10	33.12 32.84	26/III 26 28/III 27	
σ_t	27.15 27.08	.. 27.09	26.41 26.16	26.37 26.18	26.33 25.98	26/III 26 28/III 27	
O_2	7.17 7.49	.. 7.48	7.22 7.69	7.38 7.52	7.23 7.55	26/III 26 28/III 27	
M %	104.8 110.5	.. 109.8	99.0 108.1	100.9 105.6	98.8 103.9	26/III 26 28/III 27	

other hand, were taken at a depth of 10 m., since we must assume that the specimens measured at that time were in stages which are more bound to the upper layers of water. We know from Lebour (16) that at Plymouth under the existing conditions there was one month between the first nauplius and Stage V.

We see from this table that the temperature in 1927 at the inner stations was generally higher that in 1926. There were nearly constant proportions between the lines $^{26}/_{3}$ 26 and $^{28}/_{3}$ 27, where the difference was slightly over 1°. This is what might be expected from a negative co-relation between conditions of tempera-

ture and length. We also see from this table that at Station E there is a quite different relationship between temperature and length than at the other Stations.

The salinity and density were slightly less at the inner stations in 1927 than in 1926. ADLER and JESPERSEN (20) do not attach any importance to these dimensions in this connection. It appears from STÖRMER's measurements (this volume, page 7) that the largest animals are from Stations 44 and 49 and the smallest from Stations 32 and 63. At the two former the salinity was somewhat less and the density somewhat greater than at the two latter stations. These were, however, the conditions in which the animals existed when they were caught. We further see from the table that there was more oxygen and a higher percentage of saturation in 1927 than in 1926. In the above mentioned instances from STÖRMER the largest animals were caught in water poor in oxygen and the smallest in water rich in oxygen.

In order to test these conditions further we can study the hydrographical conditions and the variation in length at one station during the time when the investigations took place. I here give in tabular form the results from Station A in 1926. The hydrographical data are from a depth of 10 metres one month before, as these have proved to give the best agreement.

We at once see from this table that the co-relation between length and temperature is quite good. It is calculated so that the whole number of measured specimens has been taken into consideration. The co-efficient of co-relation = — 0.54. Somewhat better is the result if the length 2.54 is selected for $^{28}/_{4}$, and somewhat poorer if the hydrographical data from the same cruise as the measurements are employed in the calculation. Of the other co-relations, the length-percentage saturation is the best, length-salinity the poorest. The same proportions are found in dealing with the other stations in the same manner. At all stations in both years there was a surprisingly good negative co-relation between the percentage of saturation and the length. The co-relation is not quite so good when we deal with the variation from station to station in one line, of which Table 15 gives an instance. It is probable that the agreement is still less in material gathered from a whole year. The existing material, however, is not sufficient to permit a further study of this relationship. We will therefore restrict ourselves to the statement that in the region investigated the temperature directly or in-

Table 16. Measurements of *Cephalothorax* in mms and the Hydrographical Conditions in the previous Month at Station A. 1926.

Date	28/IV	12/V	24/VI	20/VII
L.....	2.65	2.45	2.41	2.33
T°	3.92	4.52	6.88	7.62
S °/₀₀	33.12	32.83	33.17	33.40
σ_t	26.33	26.04	26.01	26.09
O_2	7.23	8.22	7.88	7.60
M °/₀.....	98.8	114.2	115.3	113.4
Date	26/III	10/IV	1/VI	24/VI

directly determines the length, whilst the other hydrographical conditions are of minor importance and only more or less by chance give a good co-relation with the length.

The Fjord.

As regards the fjord, individuals were measured only three times in 1927, viz. $^{22}/_{3}$, $^{21}/_{6}$ and $^{11}/_{8}$ each time from the innermost Station Rfj. The results were the following: $^{22}/_{3}$ — 2.28, $^{21}/_{6}$ — 2.50, $^{11}/_{8}$ — 2.50. In all three cases the specimens were taken in deep hauls from layers where the temperatures are fairly constant from 7°.05 to 7°.40 and salinity about 34.70 $^{0}/_{00}$. The percentage af saturation for oxygen was also very low and about 80 in all three cases. There would thus appear to be in all the hydrographical observations nothing to cause a difference in length between the first and the other measurements, but perhaps agreement between the last two. The first and second lengths agree quite well with all those from the bank, whilst the specimens taken $^{11}/_{8}$ are considerably larger than those on the bank. This appears to indicate that the specimens on $^{21}/_{6}$ and $^{11}/_{8}$ belong to the same population and originated in the same spawning.

Outside the Bank.

We have measurements from the long section off the bank from 1924 to 1927 inclusively, as will appear from the following table.

To this table there belongs a key which is given on page 19 and which shews at what stations the measurements were taken.

Table 17. Measurements in mms of *Cephalothorax* of Stage V of *Calanus finmarchicus* off the Bank 1924—1927.

1924	11-13/VII	2.54	..	..	2.25	..	2.38	..	2.44
1925	17/VIII	..	..	..	2.46	2.27	2.34	2.15	..
1926	10-11/VI	..	2.40	..	..	2.34	2.43	2.53	2.48
1927	31/VII-1/VIII	2.42	..	2.32	..	2.43	2.40	2.38	2.44

In addition to the above there are measurements from the following stations with the results given here.

1924: S/S "Michael Sars" St. 5 (see Fig. 3) 2.36, St. 70 and 73 (Störmer, this volume, fig 4) 2.47 and 2.31 respectively.

1926: S/S "Skagerak" $^{9}/_{6}$ pos.: N 59°8′ E 0°37′, 2.37.

1927: S/S "Östkap" $^{14}/_{7}$ 63 NW. Björnsund 2.38, $^{16}/_{7}$ Tampen 2.48.

In 1924 the individuals from Tampen were fairly large in July, and the animals off the west coast of Norway and in the middle of the Gulf Stream were slightly smaller, although of the same order of size as the former. The animals from

Station 11 were much smaller and those north of Faroes were considerably larger. In September to the east of Faroes the length was also fairly great, whilst on the Shetlands' Bank, Station 73, it was somewhat smaller than in July at Tampen.

In August 1925 the length at the innermost station was very small, somewhat greater at the two middle stations and fairly large at the outer station.

In June 1926 the lengths at the three innermost stations were great, somewhat less at Station 74 and a little greater at the outermost station. Measurements in June from the Shetlands' Bank (Steamship "Skagerak" $^{9}/_{6}$) gave somewhat the same size as from those waters in 1924.

In 1927 in the long cruise there was about the same length at the four inner and the outer station, whilst the length at the next outermost station was somewhat less. The limiting values for the true mean value thus barely merge into each other from Station 141 to Station 142 and to Station 143. Measurements at approximately the same place as Station 139 on $^{14}/_{7}$ (S/S "Östkap") gave the same result as on $^{31}/_{7}$. Measurements of Stage V from Tampen $^{16}/_{7}$ 27 gave almost the same result as the measurements at the same place (Station 7) July 1924.

All these measurements, especially those from July 1924 and June 1926 shew that the individuals at the inside and at the inner border of the Gulf Stream are large, small towards the outer border of the Gulf Stream and then large outside the Gulf Stream. This again supports what has already been said regarding the Gulf Stream as a border between two regions, the difference in length and in the distribution of stages shewing that there are different populations.

The measurements from August are not such good indicators of this, nor were the total figures and the distribution of stages.

The vertical Distribution of Calanus finmarchicus.

Damas (05) states that in the Norwegian Sea 200 m. are the lowest limits for the general occurrence of *Calanus*. In the investigations from Möre, where the depth has permitted, 200 m. as a rule was the lowest limit of our vertical hauls, although we were aware that *Calanus* occurs at considerably greater depths. Thus off Iceland Paulsen (09) found that it was very common down to 500 m., and Damas and Koefoed (07) found it in the Northern Norwegian Sea down to 1200 m. In the fjords, according to the investigations of Nordgaard and Jörgensen (05), *Calanus* is commonly distributed in winter between 300 and 200 m. In 1927 at our stations in Romsdalsfjord we therefore also took our vertical hauls right from the bottom at depths of 350 to 400 ms. The vertical daily migrations have been minutely studied by Esterley (12) and Russell (25, 26, 27) who, however, both treated all stages combined. For such an investigation vertical hauls alone are not very well suited, and a somewhat different method of work to that which we employed

is also nesessary. Several authors, latest Störmer (this volume), have dealt with the circumstance that the younger stages of *Calanus* remain nearer the surface than the older stages.

The Bank 1926.

In 1926 at the bank off Möre vertical hauls were taken on all cruises, except in the first when the stock was in minimum at depths of 20—0 m., 50—20 m. and 200—50 m. from the bottom respectively. By summing up each stage throughout all stations and during the whole periods referred to in the three types of hauls we obtain a good idea of the depth distribution of each stage. In the following table this distribution is calculated in per cent of the total number of each stage.

It appears from this that all stages, except Stages V and VI ♂, have their maximum distribution above 20 m. This is also evident in the figure shewing the total of *Calanus* of which 52 % belonged to the haul 20—0 m. 35 % of the total amount belonged to the haul 50—20 m. where we find the maximum of Stage V and 13 % belonged to the deepest haul below 50 m. This haul is very poor in all stages except V and VI ♂, the latter being just as common in this haul as in the haul 50—20 m.

Table 18. The Percentwise Distribution of each Stage of *Calanus finmarchicus* in the Hauls made in 1926.

Stages	0 ↑ 20	20 ↑ 50	50 ↑
N.....	60	35	5
I.....	59	38	3
II.....	51	43	6
III.....	56	42	2
IV.....	48	45	7
V.....	40	43	17
VI♀	52	39	9
VI♂	26	37	37
All Stages	52	35	13

1927.

In 1927 hauls were taken at the same depth as in the previous year on the bank on two cruises only, namely $^{3-4}/_{5}$ and $^{1}/_{6}$, whilst the hauls on all the other cruises were taken in the depths 50—0 m. and 200—50 m. from the bottom respectively. The result is given in two tables, the two cruises mentioned being separately dealt with in Table 19.

This shews very nearly the same results as the preceding table. The younger stages are found to an even more marked extent in the haul 20—0 m. and Stage V has also its maximum in the latter, whilst stages VI ♂ and ♀ have their maximum in the haul 50—20 m.

We see from table 20 that the maximum of the sum of all stages and of nauplii and Stages I, IV and V are in the upper hauls from 50—0 m.

However, there are of all stages but especially of Stages I, II and III a surprisingly high percentage in the lower hauls, which has its explanation in the circumstance that the great majority of these stages were found on the cruise $^{28-29}/_{3}$, Stations A and B, where Stages I, II, III and IV almost exclusively and in large quantities

were found in the lower hauls from 175 or 150—50 m. respectively. This is scarcely due to conditions of light as Stations A and B were taken respectively at 10 and 19.30 o'clock. The hydrographical conditions as well as the stock of phyto-plankton (Gran, this volume) shew, however, that at these stations there is a marked packing of the

Table 19. The Percentwise Distribution of each Stage of *Calanus finmarchicus* in the Hauls made $^{3-4}/_{5}$ and $^{1}/_{6}$ 1927.

Stages	0 ↑ 20	20 ↑ 50	50 ↑
N.....	86	10	4
I.....	93	7	0
II.....	68	30	2
III.....	69	29	2
IV.....	59	30	8
V.....	44	33	23
VI♀.....	41	49	10
VI♂.....	23	40	37
All Stages	56	32	12

Table 20. The other cruises 1927.

Stages	0 ↑ 50	50 ↑
N.....	76	24
I.....	51	49
II.....	40	60
III.....	41	59
IV.....	65	35
V.....	83	17
VI♀	48	52
VI♂	13	87
All Stages	65	35

coastal water layers which may have carried *Calanus* copepodites and nauplii down to the depths where they have remained, partly on account of small powers of motion and partly because the conditions with a great deal of phyto-plankton and a high content of oxygen were favourable also at that depth.

The Fjord.

In 1927 the conditions in the fjord were those shewn in Table 21.

The maximum of the sum of *Calanus* was here found below the depth of 50 m. In reality it was found below 150 metres, as the bulk consisted of Stage V, almost all of which was found below that depth. The distribution of the stages is very nearly ideal, nearly all nauplii and Stages I, II and III being in the upper hauls with a decreasing percentage value from nauplii to Stage III. The table also shews something which several authors have pointed out, viz. that Stage VI ♀ stays in somewhat higher layers of water than Stage VI ♂.

The results of these tables may be summed up in the following manner: The total of *Calanus finmarchicus* on the bank had its largest number above 20 m. and as a rule there were only small quantities below 50 m. This must of course be due partly to the large number of nauplii and smaller copepodite stages which

dominate the stock. But to some extent the larger stages of *Calanus* have also their maximum above 20 m. In the fjord the maximum of the total sum was below 50 m. Nauplii and Copepodite Stages I and II are undoubtedly bound to the upper layers of water, since as previously mentioned, with the exception of $^{28\text{-}29}/_{3}$ 27 they all had their maximum over 20 m. and were almost lacking below 50 m., both on the bank and in the fjord. Stage III also had its greatest extent above 20 m., but had also a high percentage between 50—20 m. At any rate this stage appears in the fjord to seek the deeper layers of water voluntarily or by sinking, 45 % of the stock of III being below 50 m. 91 % of Stage IV were found in the fjord below 50 m., whilst that stage on the bank had its maximum above 20 m., but also a very high percentage between 50 and 20 m. This stage thus exhibits very much the same features as Stage V, which had 97 % in the fjord below 50 m. and which as previously mentioned had its maximum distribution below 150 m. there. The largest number of Stage V on the bank was over 50 m., partly with a maximum in the haul 50—20 m., but there were also many, from 17—23 %, below 50 m. Stage VI ♀ on the bank had its maximum above 50 m., partly above 20 m. and had only a small percentage below 50 m., whilst in the fjord that stage had its maximum below 50 m., but with a high percentage above 50 m. Stage VI ♂ had its maximum distribution below 20 m., to some extent as in the fjord, with a maximum below 50 m. A relatively low percentage was found above 20 m.

Table 21. The Percentwise Distribution of each Stage of *Calanus finmarchicus* in the various Hauls, the Fjord, 1927.

Stages	0 ↑ 50	50 ↑ (350) 400
N.	96	4
I.	86	14
II.	82	18
III.	55	45
IV.	9	91
V.	3	97
VI ♀	36	64
VI ♂	8	92
All Stages	43	57

Amongst the most interesting observations, I would draw attention to the striking poverty in *Calanus* below 50 m., and to some extent below 20 m. at Stations D and E in the cruises $^{24\text{-}25}/_{6}$, $^{20}/_{7}$ 1926 and $^{1}/_{6}$, $^{29}/_{6}$ and $^{31}/_{7}$ 1927. All stations were taken with the sun low in the heavens, in some cases below the horizon. This circumstance may therefore be regarded as a result of a daily migration upwards towards decreasing light. The circumstance that on these occasions the Gulf Stream lies below a depth of 20—50 m. with water poor in oxygen and a salinity of 35—35.25‰, may possibly also cause *Calanus* to stay in the upper layers of water where there are more favourable conditions in the form of more phyto-plankton and oxygen.

Right at the surface, like large red clouds, I have only observed *Calanus finmarchicus* at Möre 3 times, although according to statements made by fishermen and whalers it is a common phenomenon in those waters. The observations were taken as follows:

1) Station E $^{29}/_{3}$ 26, 13 o'clock, calm and sun.
2) Tampen, $^{17}/_{7}$ 27, 23 o'clock, after sunset.
3) NW at Statt 35′, $^{21}/_{7}$ 27, 18.30 o'clock, hazy and cloudy weather.

In all 3 cases the "red bait" was the prey of the *Balaenoptera borealis* and basking shark, *Cetorhinus maximus*. The phenomenon, which has several times been observed by others, is regarded by Willey (19) to be uncommon, and he considers that it is due to conditions of current. Bigelow (26) observed the same in water where, in his opinion, it could not be due to current. It will be observed that our three observations are all from localities where the currents are very strong. This kind of concentration, to a greater or lesser extent in all layers of water, is undoubtedly the basis of the general opinion, which is shared by most investigators, that the occurrence and distribution of *Calanus* is irregular. Esterley (12) therefore maintains that all kinds of standardisation are unnecessary. On the other hand the continuity existing in the stock of *Calanus* from cruise to cruise, and from station to station in the Möre region, would appear to indicate that the distribution is not more irregular than that the use of a method like the one here employed is justifiable.

Calanus finmarchicus in Relation to Temperature and Salinity at Möre.

According to Farran (11) *Calanus finmarchicus* is eurythermal and stenohaline. According to Cleve the limits of temperature in the northern Atlantic are from 0.2° to 22°. As limits of salinity he gives 33.5 ‰—35.3 ‰. Bigelow (26) has observed living *Calanus* in water at 24°.44, and he also found adult spawning animals in water with a salinity of 29—30 ‰. It would thus appear certain that Farran's lower limits of salinity are somewhat too high. At Möre our observations were well within these limits or coincided with them. The extreme temperatures are 2°.99 and 13°.42, both at a depth of 1 m.

A salinity of 35.32 ‰ has often been observed at Station E, 75—100 m. deep, but it is characteristic that both at Station E and Station D, where the salinity in the depths exceeds 35.2 ‰, the lower hauls below 50—20 m. are, as a rule, remarkably poor in *Calanus finmarchicus*. A quite low salinity was observed at a depth of 1 m. at stations in the fjord, and in some cases at Stations A and B in the summer, as low as 20.53 ‰. As we have no towing hauls at the surface at these stations, we cannot assume with certainty that *Calanus* was taken in a much lower salinity than that which we find at the lower limit of the upper hauls viz. 50 or 20 m. The lowest salinity found was thus 32.43 ‰. Moreover the upper hauls are always poor in *Calanus* where the salinity at a depth of 10 m. is below 32—32.50 ‰.

According to Damas (05) the spawning of *Calanus* takes place in the Norwegian sea between 4° and 6° and with a salinity of about 34.90 ‰. At Möre, where we have spawning in February—March, it must take place in waters with a

temperature of 4° to 5°.5 and a salinity of 33.0 to 33.5. The next spawning in May and June must have somewhat wider limits, possibly from 5° to 7°.5 and from 33 ‰ to 34 ‰. If the immigrated stock of adult animals which is found at Station E in April to May, spawns under the existing conditions, it is referred to a temperature of 7° to 7°.5 and a salinity of 34.5 ‰ to 35.10 ‰. We should thus for Möre in the years 1925, 1926 and 1927 have limits of temperature and salinity for spawning from 4°—7°.5 and from 33 ‰—35.10 ‰.

In the deeper parts of the fjord during the whole period of investigation there were very homogeneous conditions, viz. a temperature of 7°—7°.5 and salinity from 34.20 ‰—34.90 ‰. In these circumstances we must assume that the local stock spends the winter in those waters.

Calanus hyperboreus, Krøyer.

According to earlier investigations this large Arctic copepod is more accidental and scarce in its occurrence on the banks off the west coast of Norway, but it is more common in the deep Norwegian fjords, where Sars (03) regards it as a relict species.

In our investigations from Möre we found it to be common, to some extent in large numbers in the Romsdalfjord, Forfjord and Julsund, whilst on the bank outside it always occurred in small and insignificant quantities.

Numerical Occurrence.

The numerical occurrence in our Samples will appear from the following table:

Table 22. Number of *Calanus hyperboreus* in the total Hauls at the Stations in 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.
1926	16-18/III	..	..	..	..	149		
	9-10/IV	285	..	..	..	..		
	28-29/IV	..	..	..	..	201		
	1-2/VI	..	49	..	..	..		
1927	22/III					617	309	924
	28-29/III	18	81	186	204	482	..	..
	3-4/V	29	36	..	12	457	..	..
	1/VI	..	..	..	41	73	..	..
	21/VI						1547	7861
	11/VIII						126	494

In addition there are a number of stations at which the species has been noted as occurring but with less than 1 % of the total number of copepods. In this manner it is of course difficult to obtain any continuity in this table. In 1926 it seems as if there were two centres for the distribution of *Calanus hyperboreus*, one at Station E and another at Station A. A relatively large number occurs at Station E which, however, has only 1 % of the stock of copepods simultaneously with the invasion of *Calanus finmarchicus*. It will be seen from the table for 1927 that in the fjord stations as early as March 22nd there is a large number of *Calanus hyperboreus*. In the following cruise there is a considerable stock at Station A and decreasing numbers outwards to Station E. After June 1st it entirely disappeared from the bank in both years. On June 21st 1927 there was noted in the fjord the largest stock which on the whole had been observed at Möre. In the deepest haul at Station Rfj. *Calanus hyperboreus* thus amounted to 55 % of the stock of copepods.

On August 11th the stock in the fjord had decreased to a remarkable extent and in the deepest hauls at Station Rfj. amounted to only 13 % on that occasion.

A method like the one here employed is naturally not very well suited for such a large and scanty copepod as *Calanus hyperboreus*, but nevertheless we can with advantage study the distribution of stages at the comparatively rich fjord stations.

Distribution of Stages.

Table 23. Distribution of Stages of *Calanus hyperboreus* at Stations in the Fjord 1927.

	22/III			21/VI		11/VIII	
	St. A.	St. Ffj.	St. Rfj.	St. Ffj.	St. Rfj.	St. Ffj.	St. Rfj.
♂	..	..	..	..	..	..	..
♀.....	16	179	79	..	..	..	38
V	..	..	..	560	2993	126	190
IV	6	..	54	987	4865	..	266
III.....	115	35	194	..	..	..	..
II.....	258	84	527	..	..	..	..
I.....	224	22	73	..	..	..	..

We see from Table 23 that on March 22nd there was a maximum of Stage II, somewhat fewer of Stage I, III and VI ♀, few of Stage IV, whilst Stages V, VI ♂ were absent from the samples. There are presumably also a number of nauplii which are placed with *Calanus finmarchicus* which belongs to that species (see page 33). From this we may conclude that Spawning began in February and was probably still going on at the end of March. This entirely agrees with Nordgaards observations in the fjords in North Norway (Nordgaard and Jörgensen 05).

On June 21st there were only Stages IV and V in the fjord and almost twice the number of Stage IV than of Stage V. On August 11th there was still a maximum of Stage IV at the innermost Station, but it was not so predominant. In addition to Stage V there were also some of Stage VI ♀. The colossal increase in numbers from March 22nd to June 21st should indicate that the younger stages on March 22nd had not yet reached their maximum. Otherwise the great change in numbers, especially the decrease on August 11th may also possibly indicate that the samples are not representative for the stock. It is at any rate a possible factor which in view of the few observations must not be under-estimated. That the copepodite Stages IV and V on June 21st come from spawning in February to March is probably certain. At the present time it cannot be decided whether this generation in its entirety in August and later reaches the adult stage, and if so whether a new spawning takes place. The specimens of *Calanus hyperboreus* found on the bank were almost all of Stages III, IV and V. A few of Stage II were found at Station C on March 28th 1927. No stages beyond those here mentioned were observed outside the fjord stations. The distribution shows a maximum of Stage III in March—April and of Stages IV and V in May and June.

It will appear from these data with all desirable distinctness that *Calanus hyperboreus* is stationary in the fjord, and that the latter constitutes its region of spawning from which also come those specimens which are occasionally found over the bank. A possibility of migration from the Norwegian Sea is only found on Storeggen and during the time over which the investigations extend this has at any rate not taken place to any great extent.

In the long line of stations *Calanus hyperboreus* was found at Stations 11, 12 and 13 from July 12th — 13th 1924, and further at Station 76 on June 11th 1926. All these stations are situated at the outer edge of the Gulf Stream so that, no doubt, we are here dealing with specimens which originated from the Norwegian Sea. All the specimens were of Stages III, IV and V, which indicates a spawning and period of development as in the fjord.

Vertical Distribution.

The vertical distribution of *Calanus hyperboreus* in the fjord and at Station A on March 22nd was very characteristic, nearly all the copepodites I, II and III and a number of Stages IV and VI ♀ being found in the hauls from 50—20 m. A few were found in 20—0 m., but there were none of the small copepodites below 50 m. Stage VI ♀ had its maximum below 200 m., but was otherwise found with few specimens of Stage IV, in some cases also in the overlying hauls.

On June 21st and August 11th all specimens of Stages IV and V were, without exception, found below 150 m.

Out on the bank the distribution of depth is less regular, *Calanus hyperboreus*

being principally found in the deeper hauls below 50 and 100 m., but in some cases, especially in March—April Stages III and IV were found in hauls 20—0 m. This is likewise the case with specimens at Station E on April 9th 1926. Vertical migration towards decreasing sunlight possibly plays a part in this case, since the station was taken at 18 o'clock just before sunset.

The vertical distribution is thus on the whole nearly the same as that of *Calanus finmarchicus.*

Measurements.

Only a small number of *Calanus hyperboreus* have been measured. In the fjord Stage V appeared to vary between 4.05 mm. and 4.50 mm. and Stage VI ♀ between 5.18 and 5.63 mm. At Station E on April 9th 1926 Stage V varied between 4.53 and 4.89 mm. and a Stage VI ♀ measured gave the result 6.07 mm. All measurements concern cephalothorax. The quite considerable difference in length between the two cases supports the idea that *Calanus hyperboreus* on Storeggen had migrated from without, and did not originate in the coastal water, just as was shewn previously in the case of *Calanus finmarchicus.*

Hydrographical Conditions.

Calanus hyperboreus in the depths of Romsdal- and Forfjords lives in waters which from March—August and presumably the whole year have very homogeneous hydrographical conditions. The temperature varies below a depth of 150 m. from 7.0° to 7.5° and the salinity from 34.4 ‰ to 35.0 ‰. The younger stages which in March have their maximum distribution between 50 and 20 m., have a temperature varying from 5° to 7° and a salinity from 32.5 ‰ to 34 ‰. The stock at Station E of April 9th 1926 was found in water with a temperature of 7.4° to 7.5° and a salinity of 34.3 ‰ to 35 ‰. Within the limits of temperature and salinity here mentioned, all specimens with a few exceptions were found on the bank, *Calanus hyperboreus* having quite disappeared after June 1st, when the temperature began to rise above 7° to 7.5° in the upper layers of water. Whilst these limits of salinity are in accordance with those given by Farran (11), the upper limits of temperature, 7.5°, are higher than any temperature reported by him.

Euchæta norvegica (Boeck).

According to Sars (03) Euchæta norvegica is common in the deep Norwegian fjords and according to Farran (11) it is found distributed over the whole of the Norwegian Sea, except in a belt along the coast of Norway from Romsdal to Lofoten. These statements correspond to the conditions which we found at Möre, viz. that this species has the same distribution as *Calanus hyperboreus*, but occurs even more sparingly.

Numerical Occurrence.

In 1925 Euchæta was not observed, and in 1926 at two stations only, viz. (1) Station B March 26th, five specimens in a haul 100—50 m. and (2) Station E July 20th two specimens from 200—120 m.

In 1927 for some unknown reason it was more common, having an occurrence which is shewn in Table 24.

Table 24. Number of Euchæta norvegica in total Hauls at Stations in 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.
	22/III					196	565	199
	28-29/III	55	..	..	..	68		
	1/VI	24	..	..	..	..		
1927	21/VI						107	758
	29/VI	15	..	..	..	..		
	31/VII	28	41	..	..	..		
	11/VIII						63	76

We see from this table that Euchæta always, and in some cases in relatively large numbers, occurs in the fjord and in March also at Station A. Outside these Stations it frequently occurs in small numbers at Station E and once at Station D.

We may take it for granted that Euchæta is stationary in the fjord. At Eggen its occurrence is probably due to migration from the deeper Norwegian Sea, from Gran's Euchæta region (Gran 02), since it appears never to have been able to pass the more shallow part of the coast bank.

Distribution of Stages.

I have not determined the stages of Euchæta Norvegica in such a way that I can here give any absolute figures for the distribution of the stages. All stages were present in all three cruises in the fjord, although there were indications that females with egg sacs were more frequent in March than in July and August. Nauplii of which there were many in March and June, were lacking in August. Intervening copepodite stages were most common in June. There thus undoubtedly occurs spawning in the Spring and Summer months.

Vertical Distribution.

The vertical distribution of Euchæta norvegica in the fjord is shewn in the following table where the three cruises are treated in combination.

In one case Station Ffj. March 22nd some Euchæta were taken at depths above 50 m. These 107 specimens were mainly adult ♀♀, but without egg sacs. Otherwise there were some in the hauls between 100—50 and 150—50 m. respectively, but the bulk of Euchæta were taken below 150 and 200 m. The various

Table 25. Distribution of Numbers of Euchæta norvegica in the various Hauls in the Fjord 1927.

Hauls	St. A.	St. Ffj.	St. Rfj.
20— 0 m.....	..	..	..
50— 20 —	..	107	..
50— 0 —	..	..	..
100— 50 —	86	36	98
150— 50 —	..	37	45
175—100 —	101	..	..
200—100 —	..	201	36
400—150 —	..	133	789
400—200 —	..	221	65

stages are here distributed in the same manner as that found by Störmer (27) all nauplii and the smallest copepodites without exception being taken below 150 m. The fact that these less mobile stages are found in deep waters gives an excellent explanation of the circumstance that the stock does not spread over the bank. Out at Eggen Euchæta is always found in the deepest haul.

The hydrographical conditions to which this species is exposed are very nearly the same as those for *Calanus hyperboreus*, although at Eggen it is taken in water with a temperature of about 8° and a salinity of about 35.30 ‰.

Metridia longa, Lubbock.

From our previous knowledge of *Metridia longa* in our waters (Sars 03, Farran 11) we were prepared for a distribution at Möre like that found in the case of *Calanus hyperboreus* and *Euchæta norvegica*. As will be seen from Table 26 this is also the case, and *Metridia longa* occurs in extremely small numbers, even though it is always present in the fjord and frequently occurs at Station E.

Numerical Distribution.

At Eggen the occurrence is of the same dimensions as in the case of *Euchæta norvegica* (Table 24). In the fjord and at Station A the figures are somewhat smaller than they were for Euchæta, but this may be due to the circumstance that small copepodites of metridia were not determined as regards species.

Table 26. Number of *Metridia longa* in the total Hauls at the Stations in 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.
	26-27/III	..	..	..	3	..		
	28-29/IV	56	..	..	..	..		
1926	12/V	146	..	..	..	212		
	1-2/VI	196	..	..	..	..		
	20/VII	5	..	..	..	..		
	1-2/III	95	..	..	..	.		
	22/III						105	90
	28-29/III	96	..	..	204	..		
	3-4/V	83	33	..	..	..		
1927	1/VI	6	..	..	69	..		
	21/VI						232	196
	29/VI	30	..	..	..	..		
	31/VII	140	..	..	..	..		
	11/VIII						63	.

In addition to the occurrence at Station E *Metridia longa* was caught once at Station D and 3 times at Station B. It seems probable, as in the case of the two previous species, that the specimens at Stations A and B came from the fjord where, no doubt, the species occurs all the year round and the specimens at Stations D and E came from the deeper Norwegian Sea where we also know the species to be common.

Vertical Distribution.

All specimens of *Metridia longa* at the bank were taken at depths below 50 m. and the largest number was found at stations where the hauls were always made as deep as below 100 or 200 m. On March 22nd 1927 the largest number was taken in the fjord at depths above 50 m. and at Station Rfj. even above 20 m. There is thereby a possibility of spreading out of the fjord itself. In the two last cruises in the fjord all were taken below 150 m. which is in accordance with Sars' statement of depth (03). It seems possible that *Metridia longa* like *Euchæta norvegica* and *Calanus hyperboreus* breeds in the fjord district although we have no definite observations on this point. However, this assumption may possibly explain the circumstance that a large number of adult specimens were found above 50 m. on March 22nd.

The hydrographical conditions at Möre are such that the temperature and salinity at places where *Metridia longa* was found, in some cases exceed the limits which Farran stated to be normal, but which nevertheless lie within the extreme cases mentioned by Bigelow (26). The ordinary temperature of the water at the

bottom of the fjord thus goes up to 7.5°, whilst FARRAN gives 6.75° as the upper limits. At Storeggen *Metridia longa* was found in small numbers in water between 8.38° and 9.60°. The extreme salinities are from about 32 ‰ at Station Rfj. on March 22nd 1927 to 35.3 ‰ at Station E.

Metridia lucens, BOECK.

Metridia lucens is one of the most common of larger copepods occurring on the bank off Möre, whilst in the fjord it is practically unknown. This is in close agreement with its other occurrence, which is of a somewhat more southern character than *Metridia longas.* (SARS 03, FARRAN 11).

Numerical Distribution.

The numerical occurrence on the bank in 1926 and 1927 is shewn in Table 27.

We here see that *Metridia lucens* was present in all the cruises over the bank in both years, but only once in three cruises in the fjord was found so far in as Forfjord. Its occurrence on the bank was very occasional both as regards place, time and numbers. The species was found most regularly and certainly at Station B. The stock at Eggen, in any case from the month of May onwards was generally richer than at the other stations. The stock was most meagre in the first line of stations in March and richest in June to July. This occurrence has certain features

Table 27. Number of *Metridia lucens* in the total Hauls at the Stations in 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.
1926	16-18/III	18	78	46	95	..		
	26-27/III	..	..	..	5	..		
	9-10/IV	..	..	..	57	..		
	28-29/IV	56	129	..	156	41		
	12/V	146	..	..	239	..		
	1-2/VI	273	49	..	122	5		
	24-25/VI	197	223	322	288	123		
	20/VII	83	22	..	..	44		
1927	1-2/III	..	18	46	..	10		
	28-29/III	428	..	..	455	68		
	3-4/V	15	66	1	104	..		
	1/VI	28	..	99	454	368		
	21/VI	..	..	..	..	387	7	..
	29/VI	137	..	60	641	..		
	31/VII	1068	455	..	..	..		

in common with what we found in the case of *Calanus finmarchicus*, since judging from the poverty of the fjord *Metridia lucens* receives no additions from the local coastal water. If compared with FARRAN's results (11), it seems as if the masses of water in the border layers of the Gulf Stream are where we find the most abundant quantity and that additions from the West are thus the most important.

Farther in on the bank at Station B, however, the stock presumably comes into our line of observation with the Baltic Stream from the Skagerack.

Vertical Distribution.

Metridia lucens migrates vertically in all waters, in some cases as at San Diego from the considerable depth of 200 to 300 fathoms up to the surface towards declining sunlight (ESTERLEY 12). FARRAN (11) points out the difficulty of determining the depths and hydrographical conditions which are most favourable for the species precisely on account of their marked vertical migration. At Möre where majority of the stations were taken by daylight *Metridia lucens* was as a rule found at depths below 20 m. and the maximum number was mostly below 50 m.

We have, however, a great many exceptions to this. Thus at Station D on July 31st 1927 72 % of all *Metridia lucens* were found above 20 m. at 13 o'clock in sunshine. On the other hand there are instances to shew that all *Metridia lucens* are found below 100 m. at 23 o'clock. There would appear to be on the whole no absolute law for the migration towards the surface at night and towards the depth in daytime, even if the tendency clearly shewn in the existing scanty material is noticeable.

Metridia lucens is found in such widely different hydrographical conditions that FARRAN gives the limits of its occurrence from 4.83° to 16.10° as regards temperature and from 28.1 ‰ to 35.4 ‰ for salinity. The conditions at Möre lie well within these limits, and on account of its irregular occurrence it is difficult to state the temperature or salinity which might be considered to be the most favorable within the interval. The largest number caught, namely at Station E on July 31st 1927 were found in water at a temperature from 7.75° to 9.0° and salinity about 35.3 ‰. The largest number taken at Station B on June 29th 1927 were in water at a temperature of 7.08° to 7.48° and salinity 34.47 ‰ to 35.07 ‰.

Copepodites of Metridia sp.

In both 1926 and 1927 many copepodite stages of *Metridia* were found at Möre, but these were not determined when counted and will therefore here be dealt with collectively. The value of this material is naturally not great, for the possibility is present that they may belong to two related but quite different species from a biological point of view.

Numerical Distribution.

Table 28. Number of *Metridia* Copepodites in the total Hauls at the Stations in 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
	26-27/III	..	..	..	33	17			10
	9-10/IV	..	..	45	..	..			9
	28-29/IV	451	776	..	311	..			308
1926	12/V	853	740	296	1920	1777			918
	1-2/VI	353	261	918	1264	75			574
	24-25/VI	218	55	..	96	..			54
	20/VII	454	88	130	26	142			188
	1-2/III	24	51	15	87	99			55
	22/III					66	147	23	..
	28-29/III	45	495	744	1020	203			501
	3-4/V	119	2148	297	1068	735			875
1927	1/VI	139	..	270	1530	408			469
	21/VI					194	114	..	..
	29/VI	608	24	134	1018	345			426
	31/VII	171	849	223	696	420			472
	11/VIII						290	..	..

The numerical distribution of these copepodites is shewn in Table 28.

1926.

In 1926 there were no copepodites in the first cruise on March 16th and the next two cruises were also meagre. The maximum number was found in the cruise on May 12th. Station B being the richest as it also was in the following cruise on June 1st. The total stock decreased later on in the summer. The average figures in the last column of table 28 illustrates this.

1927.

In 1927 the stock was also small to begin with, but as early as March 28th —March 29th the average figure for the bank was 501. The maximum for that year was also in the May cruise. On June 1st the stock was one-half of the maximum and remained at that height throughout the summer. Station B was also as a rule the richest that year. On May 3rd Station D had the largest number of copepodites, namely 2185 specimens, which on the whole were counted at any station in those two years. At that station the *Metridia* Copepodites constituted 37 % of the number of copepods in the lower hauls from 120—50 m. This is also the largest percentage which was observed of *Metridia* Copepodites.

There was little difference between the two years. In particular it is evident that the increase in the stock began earlier in 1927 than in 1926, a fact which may

possibly be connected with the somewhat higher temperature in the latter year. Solely on the basis of the numerical predominance of *Metridia lucens* over *Metridia longa* we can assume that the majority of these copepodites belong to the former. This assumption is also supported by the relative poverty of copepodites in the fjord samples. The number appears to decrease inwards, the innermost station having only a few on the first cruise, whilst later on *Metridia* copepodites are entirely lacking. A maximum of copepodites in May is also succeeded by a maximum of *Metridia lucens* in June—July.

Vertical Distribution.

In only one case, in 1926, on May 12th at Station E 20 o'clock 50 *Metridia* Copepodites were found above 20 m. At all other stations in 1926 *Metridia* copepodites were taken below 20 m. and a distinct maximum below 50 m. In 1927 a number of copepodites were taken in the hauls 50—0 m. and also a few in the hauls 20—0 m. at the Stations D and E on May 3rd and June 1st all in the evening. Otherwise in that year, too, the maximum of *Metridia* copepodites were found below 50 m.

B. Microcalanoida.

Acartia Clausi, Giesbrecht and Acartia longiremis, Lilljeborg.

Farran (10) says regarding *Acartia Clausi* that according to its distribution, it appears to a certain extent to be dependent upon Atlantic water. On the other hand *Acartia longiremis* belongs to the coast plankton and is called Littoral by Farran, Boreal by Cleve, more Neritic than Oceanic (Farran 10). At Möre the two species supplement each other. As will appear from Table 29 *Acartia Clausi* mainly occurs off the most shallow parts of the bank and is only exceptionally found at Stations A and Ffj. *Acartia longiremis* occurs most profusely at Station A and in only 3 cases was found off Station C.

Numerical Distribution.

Acartia Clausi.

In the May cruise in 1927 *Acartia Clausi* was found in small quantities over the whole bank and in somewhat larger numbers at Station E. In the later cruise in July it was not found at all. In 1926 (Table 29) there were only small quantities in March and April with a maximum at Station B. At the end of April we found the maximum number of the Spring at Station C. On May 12th there was an unusually high number at Station A and otherwise a regular stock over the whole Bank. On the 1st to the 2nd June the species was entirely lacking. At the end of June there was again an increase at the three outer stations and at the end of July there was a large stock over the whole bank with a maximum at Station C. At the latter

Table 29. Number of *Acartia Clausi*, *Acartia longiremis* and *Acartia* copepodites in the total hauls at the Stations in 1926 and 1927.

Year	Date	Acartia Clausi					Acartia longiremis					Acartia copepodites				
		St.E.	St.D.	St.C.	St.B.	St.A.	St.E.	St.D.	St.C.	St.B.	St.A.	St.E.	St.D.	St.C.	St.B.	St.A.
1926	16-18/III	36	39	46	189	149	..	..	..	..	..	..	..	..	..	..
	26-27/III	..	..	29	25	..	..	..	..	..	67	..	..	1007	13	99
	9-10/VI	..	..	21	183	..	..	..	..	183	1318	..	96	83	..	..
	28-29/IV	299	304	768	199	..	..	..	..	156	3550	206	203	291	610	3114
	12/V	149	243	169	80	625	50	27	..	..	582	..	216	99	416	500
	1-2/VI	..	..	..	..	..	..	..	..	..	312	479	..	..	37	748
	24-25/VI	81	352	61	..	..	..	..	200	..	4078	71	272	222	1351	6254
	20/VII	294	2020	3670	1045	..	..	..	..	..	1139	2291	4611	6586	8481	401
1927	1-2/III	..	32	31	20	..	..	..	..	..	..	..	38	31	112	..
	28-29/III	..	162	..	..	..	..	..	..	251	..	98	..	..	..	348
	3-4/V	..	99	..	..	128	..	..	..	..	1020	..	72	394	..	1484
	1/VI	..	25	..	23	..	..	..	..	97	60	..	..	..	15	..
	29/VI	..	..	..	..	..	..	..	52	..	182	..	..	9	278	121
	31/VII	312	..	..	..	..	..	644	..	265	1332	468	..	210	265	780

there were 3.670 specimens, the largest number of that species ever observed at one station; in the uppermost hauls from 20—0 m. it amounted to 7 % of the entire stock of Copepods.

In 1927 the stock of *Acartia Clausi* and of *longiremis* and copepodites was considerably smaller, and the occurrence of these species was more scattered than in 1926. *Acartia Clausi* was most frequently found in that year at Station D. The largest number was found at Station E on July 31st. The species was entirely lacking on June 29th. It was found once at Station A on May 3rd and once in small numbers at Station Ffj. on August 11th.

Acartia longiremis.

Acartia longiremis was not found off the Bank in 1925. In 1926 it was lacking on the first cruise but was present on all the others at Station A, twice at Station B and once at Stations C, D and E. At Station A there was a maximum number at the end of April and at the end of June with an intervening minimum on the 1st June. In 1927 *Acartia longiremis* was present at Station A in the first four cruises, at Station B in the second, fourth and fifth cruise, once at Station C at the end of June and at Station D at the end of July. There was a maximum stock at Station A on May 4th and July 31st. *Acartia longiremis* was found in the fjord at Station Ffj. on March 22nd and at Station Ffj. and Rfj. on August 11th. It was entirely

lacking in the fjord on June 21st. Like Clausi the stock of *Acartia longiremis* was considerably poorer in individuals in 1927 than in 1926

Acartia Copepodites.

Acartia Copepodites were present on the Bank in 1926 in all cruises except the first from the 16th—18th March. They were found at nearly all stations but, however, had a marked maximum occurrence at Station A, in the last cruise on July 20th at Station B. The maximum number was found on April 28th and July 20th. There was a generally decreasing number in the lines from Station A to Station E.

In 1927 the number of copepodites like that of the two adult forms was considerably less than in 1926.

There were Copepodites in all cruises, most frequent and in the largest number at Station A where we had two maxima on May 4th and July 31st. In the fjord there were copepodites at Station Ffj. on March 22nd and at Stations Ffj. and Rfj. on August 11th. There were no copepodites in the samples on June 21st. The distribution of copepodites with a maximum at Station A and decreasing number outwards thus appears to indicate that the greater part of the copepodites belonged to *Acartia longiremis.*

Acartia Clausi, however, appeared in the cruise on July 20th 1926 in very large numbers at the four outer stations, which was also the case with copepodites but not with *longiremis.* In that case there would thus appear to be an indisputable connection between *Acartia Clausi* and the copepodites. This large stock of *Acartia Clausi* and copepodites had otherwise no parallel as late as July 31st 1927.

We may assume from the above that both species of *Acartia* spawn in the Möre region several times and both species at about the same period. There is first one spawning in March—April, which results in a maximum stock of adult animals in April—May. These spawn and the next maximum stock of adult animals occurs from the end of June to the end of July. *Acartia longiremis* appears to spawn earlier than *Acartia Clausi.* Thus in 1926 the dates were June 24th and July 20th respectively. In 1927 spawning of *Acartia longiremis* was observed as late as July 31st. There is thus a possibility that *Acartia Clausi* could appear with a maximum later in 1927 which we missed on account of the conclusion of our investigations.

Microcalanus pygmæus, G. O. Sars.

Microcalanus pygmæus appears to have the centre of its occurrence in the Norwegian Sea at depths varying from 400—100 m. (Farran 11). It is very common in our material both from the fjord and from the Bank. In some hauls between 100—50 m. it constitutes up to 56 % of the entire stock of copepods, namely at Stations D and E on June 2nd 1926. Otherwise 20—40 % are quite common in the deeper hauls over the entire area.

Numerical Distribution.

The numerical distribution in time and place is shewn in Table 30.

At the end of May and July in 1925 there was a rich stock at the outer station, whilst the other stations contain fewer specimens and the species was entirely lacking at Stations A and C.

In 1926 *Microcalanus* was very common over the whole bank and was found at all stations. The maximum number, 6012, was found at Station E on May 12th,

Table 30. Number of *Microcalanus pygmæus* in the total Hauls at the Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1925	26-28/V	9088	5742	..	1820	..			3329
	22/VII	4490	990						2740
1926	16-18/III	658	1287	182	1129	896			830
	20-27/III	233		229	137	1370			492
	9-10/IV	8	45	314	1083	67			343
	28-29/IV	3081	3584	93	2177	541			1895
	12/V	6012	1266	677	2835	3620			2880
	1-2/VI	2168	3935	479	4600	320			2100
	24-25/VI	917	2800	998	355	3385			1691
	20/VII	74	409	260	818	114			315
1927	1-2/III	2318	228	321	820	467			827
	22/III					127	325	329	..
	28-29/III	1851	1178	..	408	549			797
	3-4/V	..	297	..	328	1259			377
	1/VI	140	25	245	1730	459			520
	21/VI					1484	848	1712	..
	29/VI	261	1012	134	3973	..			1076
	31/VII	1458	410	..	1044	168			616
	11/VIII						787	266	..

but the most regular stock was found at Stations A and B. Station C on the shallow part of the Bank had a number which was always below the average number of the cruise. According to the average figures, the stock decreased from the middle of March to the middle of April, whereupon an increase in numbers occurred. The maximum number was found in the cruise on May 12th. Later on the stock decreased without any fresh increase as was the case with other *Microcalanids*.

In 1927 *Microcalanus* was also found at most stations on the bank and at all stations in the fjord. It was also that year most numerous and most common at Stations A and B, in addition to the fjord at both stations. The species was en-

tirely lacking at Station C in the third cruise and otherwise the numbers there were always below the average.

To judge from the average figures the stock decreased that year from the beginning of March to the beginning of May. The maximum stock was observed later than in the previous year, in the fjord and on the bank June 21st and June 29th respectively. The maximum in the fjord was at the innermost station and on the bank at Station B. Later on the stock decreased. In the fjord the number decreased most markedly at Station Rfj., which was possibly a displacement towards the middle and deeper part of the fjord like that which we found in the case of *Calanus finmarchicus*.

Vertical Distribution.

It at once appears from the general poverty in *Microcalanus* at Station C that it prefers the deeper parts. In a few cases, 3 in 1926 and 3 in 1927 *Microcalanus* was found in negligible numbers in hauls from 20—0 m. The stations in those cases were taken between 12.30 and 20.45 o'clock. All in the month of June. At 8 Stations in 1927 *Microcalanus*, also in small numbers was taken in the 50—0 m. haul. Otherwise the whole stock was taken in hauls below 50 m. The maximum stock in the fjord was taken in hauls 150—50 m. in depth.

Spawning.

For *Calanus finmarchicus* as well as the two *Acartia* species, all of which followed the current of coast water, we saw that the maximum number occurred simultaneously with the maximum of the larger stages, in some cases adult animals. We cannot generalise this so as to apply it also, e. g. to *Microcalanus*, since the latter stays in deeper layers of water and thus does not quite exist under the same conditions of current.

Microcalanus pygmæus ♀ in the Möre region has a Cephalothorax length varying between 0.40 and 0.54 mms. The breadth of Carapax at the same time is about .21 mms. The smaller stages are essentially less. The width of the mesh of the conical part of our net was, as will be remembered, .20 mms. and of the cylindrical part .53 mms. There is thus always the possibility that *Microcalanus* can pass through the meshes of the net. This possibility increases to probability in the case of the smaller stages. Assuming that there is periodicity in the stock of *Microcalanus*, we should then expect to find the largest catches when the largest stages have their maximum. At Möre in the two years under consideration, such was the case in March and from the middle of May until the end of June. There is thus a probability that these are also the times when spawning takes place.

The general hydrographical conditions for *Microcalanus* in the fjord and on the bank are with a temperature of about 7° and salinity between 34.0 ‰ and 35.2 ‰. It has not been found with certainty in a salinity below 33 ‰ nor in a temperature higher than 9.1°.

Pseudocalanus minutus, Kröyer.

In accordance with With (15) and Störmer (this volume) I have adopted the name *minutus* Kröyer for the species of *Pseudocalanus* occurring at Möre. The form in these waters is beyond doubt identical with that of *Pseudocalanus elongatus*, Boeck.

This copepod at Möre is the one which next to *Calanus finmarchicus* plays the most important part in the stock of copepods.

Numerical Distribution.

As will appear from Table 31 its numerical distribution is of the same order of size as that of *Calanus finmarchicus*, and like the latter *Pseudocalanus* was taken from all stations in those three years.

Table 31. Number of *Pseudocalanus minutus* in total Hauls at the Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	Average
1925	26-28/V	26696	6264	1855	2730	1694	7848
	22/VII	12572	396				2594
1926	16-18/III	125	390	1184	2732	2689	1424
	26-27/III	19	..	1813	1415	3063	1578
	9-10/IV	302	469	3480	4813	451	1913
	28-29/IV	2330	2808	1908	5139	5040	3445
	12/V	3147	2880	2323	3235	3750	3067
	1-2/VI	2459	504	1794	1964	2004	1745
	24-25/VI	1798	984	1618	1475	4273	2030
	20/VII	5415	20071	18557	17100	1363	12501
1927	1-2/III	71	306	384	855	247	373
	28-29/III	595	597	7316	7547	2828	3777
	3-4/V	442	5847	3437	3570	5195	3658
	1/VI	544	475	979	3245	732	1195
	29/VI	1442	1781	975	7053	1264	2503
	31/VII	3193	3343	1502	3943	1572	2711

The total figures do not include nauplii and the figures are to be understood as minimum values, because a large number of the copepodite Stages I, possibly also II and III, pass through the meshes in the cylindrical part of the net.

It will be seen from the table that the stock from a minimum at the beginning of March increases to a maximum in April—May, decreases to June 1st and again increases during the summer.

1925.

At the end of May 1925 the stock was specially rich at Storeggen. The numbers found there were the maximum numbers of *Pseudocalanus* found at any station

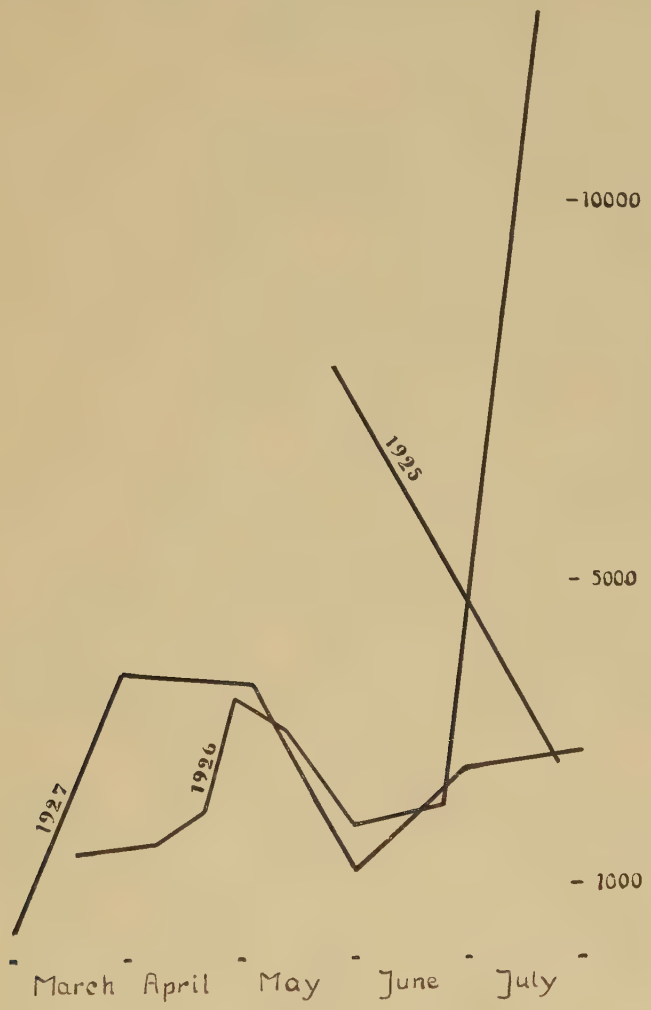

Fig. 8.

in the three years. *Pseudocalanus* then amounted to 47 % of the total number of copepods. In 1925 the stock decreased from Station E towards Station A.

1926.

In 1926 the development of the stock commenced at the inner stations decreasing in numbers from Station A outwards. At Station B the stock reached its first maximum on April 28th. It was not until as late on in that cruise that we

find at the two outer stations figures of the same dimensions as those of the average. The stock there increased until May 12th. On June 1st there was a decrease in numbers at all stations. At the end of June there was a fresh increase at Station A and at the end of July the stock at Stations B, C and D reached the maximum height of the year. At Station D *Pseudocalanus* amounted to 38 % of the stock of copepods in the upper hauls from 20—0 m.

1927.

In 1927 the stock on the bank attained its first maximum as early as March 28th and a new maximum at Station B on June 29th. The figures on the bank in July are not more than one-fourth of those which we found in July 1926. At Station E, in 1927, the stock did not reach beyond the average figure before July 31st.

There was thus some difference between the two last years even if the development of the stock took place in the same manner and the size was of the same order.

On the basis of the average figures we have constructed Fig. 8. This illustrates in an excellent manner the variations of the stock in numbers as regards the different years. The curves shew a striking agreement with those for *Calanus finmarchicus* (Fig. 2). The first maximum in the curves for *Pseudocalanus*, however, is not as large as that for *Calanus*. Just as the curve for 1925 in the case of *Calanus* indicates an essentially later development that year, the same is the case here, but the stock of *Pseudocalanus* with the existing material appears to have been larger than in the two subsequent years. In 1926 the first maximum occurs later and the second maximum occurs earlier than in 1927, just as we also found for *Calanus*. It is possible that even on July 31st 1927 *Pseudocalanus* had not yet reached its maximum.

The Fjord.

In 1927 in the fjord there was a small stock which exhibited some increase from March 22nd to June 21st. The distribution is shewn in Table 32.

Table 32. Number of *Pseudocalanus minutus* at Stations in the Fjord in 1927.

Date	St. A.	St. Ffj.	St. Rfj.
22/III	145	110	222
21/VI	945	1065	1733
11/VIII		1144	114

The distribution of figures here also reminds us somewhat of that in the case of *Calanus finmarchicus*. There was a maximum at the innermost station on

the two first cruises. On August 11th there were negligible quantities at Station Rfj. whilst the stock at Station Ffj. was still of a considerable size.

Distribution of Stages.

According to Oberg's investigations (06), and later Kraefft's (10), it is comparatively easy and certain to determine the various copepodite stages of *Pseudocalanus*. This was not done in our material from 1925 out of regard to the limited time at our disposal. In 1926 the determination was made in such a way that Stages I, II and III were taken together in one group, Stages IV and V in another and the adult stages separately.

In 1927 we went a step further, so that Stages IV and V were also taken separately. The three smallest stages were taken together. Table 33 shews the numerical distribution of the stages, the numbers at the stations being added together in such a way that the figures in the table are to be understood as the total figure for each group in the line of stations.

Table 33. Number of each Group of Stages of *Pseudocalanus minutus* in the Line of Stations in 1926 and 1927.

	Date	VI ♂	VI ♀	V	IV	III-II-I
1926	16-18/III	388	2434	3308		..
	26-27/III	300	1245	3073		1489
	9-10/IV	842	917	5481		2127
	28-29/IV	745	4070	7284		4539
	12/V	2167	4321	7254		1751
	1-2/VI	228	4511	3123		994
	24-25/VI	323	1726	7073		732
	20/VII	3589	8192	46994		3331
1927	1-2/III	101	643	256	311	524
	28-29/III	1172	3022	3921	3942	5888
	3-4/V	1779	7484	3939	2115	3335
	1/VI	453	1832	1409	1233	1010
	29/VI	380	3644	1827	3506	3494
	31/VII	..	1207	2356	3655	6125

With (15) assumes that *Pseudocalanus* spawns when adult ♂♂ are found in the stock. In that case there should be continuous spawning at Möre during the whole period over which the investigations extend. This is also the case to a certain extent, but there is undoubtedly periodicity present, since especially Stage VI ♂ has distinct maxima. In 1926 these were on May 12th and July 20th and in 1927

on May 3rd. In 1926 Stage VI ♀ had a maximum stock which extended through the cruises April 28th—29th, May 12th and June 1st—2nd, without any marked changes and a new maximum on July 20th. In 1927 this stage had a maximum on May 3rd—4th and an indication of one on June 29th. In 1926 there was a maximum of the smallest copepodites on April 28th—29th, whilst the larger stages IV and V had a maximum stock both on April 28th—29th and May 12th. All copepodites had a fresh maximum on July 20th. In 1927 there was a maximum of the small copepodites and Stage IV on March 28th—29th, whilst Stage V culminated on May 3rd—4th. On July 31st there was a new maximum on the smallest copepodites and a somewhat less marked one of the largest copepodites. We see from this that the maxima of the various stages follows successively and thus determine at least the time of a maximum spawning. On account of the striking poverty of *Pseudocalanus* at Stations E and D and to some extent in the fjord we understand that *Pseudocalanus* has the centre of its occurrence in the coast waters whilst the stock in the fjord like that of *Calanus finmarchicus* is of a local character. We can form a picture of the manner in which the development of the stock of *Pseudocalanus* takes place.

It is not until March that there is spawning at Möre of the little stock which is then found at stations in the fjord and innermost on the bank. At the same time, or most likely earlier, spawning has also taken place continually along the west coast of Norway. The new generations follow the Baltic Stream and enter our line of observation at Möre successively. Either is the spawning farther south more intense, as is reasonable, or an accumulation takes place on the bank off Romsdalen, in such a way that the stock there attains its highest numbers in April —May simultaneously with the maximum of *Calanus finmarchicus*. A considerable number of individuals in the stock, about 50 % are then adult and may be assumed to spawn in the Möre district. This cycle is repeated and at any rate in 1926 there was a maximum stock with spawning at the end of July. In 1927 there was an indication that such was approaching.

Vertical Distribution.

Pseudocalanus minutus is most commonly found above 200 m. in all waters, although it may also be found at greater depths. Thus Wolfenden (04) proved its occurrence down to 900 m., and Störmer (this volume) found that it amounted to 32 % of the stock of copepods in a haul, between 750 and 500 m. at Station 49 in Davis Strait.

At Möre *Pseudocalanus minutus* in 1926 was quite exceptionally and only in small number to be found below 50 m. and as a rule the maximum was in the 20—0 m. haul.

In 1927 the largest number was almost always found in the upper haul

from 50—0 m. Station B and to some extent Station C formed an exception to this in the cruises May 3rd, June 1st, June 29th and July 31st, a very large percentage of the stock being found below 50 m. there. — Once, viz. on May 3rd there was even a maximum in the haul 150—100 m. *Pseudocalanus* was found in the fjord down to the 400—200 m. haul, but only in negligible quantities. The distribution of the various stages in the existing material as regards depth is the same as that found by Kraefft (10) and Störmer (this volume), the younger copepodites in 1926 being as a rule found only in the upper hauls from 20—0 m. whilst the older copepodites and adult stages to some extent also have their maximum in the 50—20 m. haul.

The limits of hydrographical conditions in which this species is found are just as wide as those for *Acartia longiremis*. Thus Farran (10) gives the limits from 7.25 ‰ to 35.30 ‰ for salinity and 2.95° to 12.47° for the temperature. The upper limits of temperature are possibly a little too low, otherwise our observations at Möre fall well within these limits. The certain extreme cases are here salinity from 31.1 ‰ to 35.25 ‰ and temperature from 3.8° to 13.0°. The lowest salinity and highest temperature are the conditions in which the largest number of *Pseudocalanus* were found at Station C on July 20th 1926.

Temora longicornis, Müller.

Temora longicornis is neritic. It occurs commonly in the Skagerak, along the south and west coast of Norway and in the fjords (Sars 03, Farran 11). According to Farran it appears to have a centre for its occurrence on the Romsdal bank. Farran also observed that this copepode more markedly than any other has a tendency to gather in thick swarms, so that it is very much a matter of chance at to the picture we obtain of its occurrence if we base upon a few observations. Even if this phenomenon were noticeable in our collection from Möre, there is still a sufficient continuity present to enable us to regard with advantage the distribution as to numbers from time to time.

Numerical Distribution.

This appears from Table 34.

The average figures for *Temora longicornis* shew that the stock is very small and in some cases is lacking at the beginning of March. In 1926 there was a steady increase in numbers to a maximum in the samples from June 24th—25th. The observations for May 1925 and July also agree well with this. In 1927 the stock at the end of March was relatively high and increased in numbers until May 3rd—4th. On June 1st and 29th the stock was somewhat smaller, but the maximum for the year occurred on July 31st. No *Temora* were found in the fjord in 1927 before the last cruise, August 11th, and then only in small numbers. The distribution at the bank shews that Stations A, B and C and to some extent D are the richest

Table 34. Number of *Temora longicornis* in the total Hauls at Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1925	26-28/III	..	261	133	..	..			79
	22/VII	898	396						647
1926	16-18/III	..	..	91	..	..			18
	26-27/III	..	..	57	..	86			35
	9-10/IV	..	96	42	46	31			43
	28-29/IV	..	51	93	721	33			180
	12/V	..	458	..	80	51			118
	1-2/VI	479	..	..	..	884			271
	24-25/VI	..	80	61	982	3369			898
	20/VII	534	1517	1155	26	401			727
1927	1-2/III	..	..	..	..	..			..
	22/III					..	..	..	..
	28-29/III	..	..	819	455	332			321
	3-4/V	..	309	291	1068	606			455
	1/VI	197	25	113	45	34			83
	21/VI					7	..	..	..
	29/VI	20	332	120	557	118			229
	31/VII	1023	644	2689	2559	408			1465
	11/VIII						164	70	..

and have the most frequent occurrence. In 1926 the maximum number was found at Station A and in 1927 at Station C. In 1927, moreover, the bulk of the stock in nearly all cruises was at Station B. At Station E *Temora* was not found in any year earlier than June 1st. On July 20th 1926 *Temora longicornis* at Station D constituted 15 % of the stock of copepods in the 15—20 m. haul. Otherwise the percentage for *Temora* as a rule is between 1 and 10 %, mostly under 5 %.

Vertical Distribution.

In one case *Temora longicornis* was found in large numbers in the 150—50 m. haul, namely at Station B on April 28th 1926. Otherwise it is only exceptionally that a few specimens have been found below 50 m. In 1926 the maximum was most commonly found in the 20—0 m. haul, but also in the 50—20 m. haul. There does not appear to be any regularity in these conditions. In 1927 with a few exceptions all *Temora* were taken above 50 m. At Station C a few were taken in the 75—20 m. haul. In the previously mentioned deep hauls at Station B, April 20th 1926, and in one or two cases at Station E, *Temora longicornis* was undoubtedly taken in water with a salinity of over 34 ‰. Otherwise its general occurrence at

Möre is in water of lower salinity than 34 ‰, down to about 31 ‰. At Möre also, it does not occur in water of a temperature less than 5° and more than 14°. The largest number of *Temora* was found between 7.5° and 13°. These observations are well within the limits given by Farran (10) and Bigelow (26).

It will be understood from these data that *Temora* is scarcely stationary in the Möre region and that it is not common in the Romsdalsfjord. It is first noted on the bank at the same times as the influx of other copepods from the spawning region to the South and West of Möre. It belongs only to the coastal water, since at Eggen it is not found before the surface water has a lower salinity than 34 ‰, it is exceptionally found in higher salinity but in such cases always where the salinity in the higher layers of water is below 34 ‰. The stock at Möre thus undoubtedly comes from the Skagerak or the south and west coast of Norway. There is nothing in the hydrographical conditions to prevent spawning taking place at Möre. Adult ♀♀, as well as small copepodite stages are also found, although no actual spawning has been observed. It is not possible at present to fix any definite spawning time at Möre.

Other Calanoids.

The following species of *Calanoids* have been taken at Möre in the course of the three years in question, more or less accidentally and in small numbers: *Centropages hamatus*, Lilljeborg; *Centropages typicus*, Kröyer; *Chiridius armatus*, Boeck; *Paracalanus parvus*, Claus; *Pleuromamma robusta*, Dahl; *Rhincalanus nasutus*, Giesbrecht; *Scolecithricella minor*, Brady; and *Ætidius armatus*, Boeck.

Centropages hamatus, Lilljeborg, was taken at one station in 1925, three in 1926 and four in 1927, at disconnected periods between $^{22}/_{3}$ and $^{11}/_{8}$. Of these 8 instances, 5 were from Station A, 2 from Station C, and 1 from Station B. The greatest number was found at Station A, on April 28th, 1926, viz. 1206 specimens, 6 % of the stock of copepods. All specimens at all stations were taken in the 20—0 haul. There is no regularity in the occurrence of the species beyond the distribution as regards depth, and the fact that it appears not to go into the fjord or outside the coast water.

Centropages typicus, Kröyer, according to Scott (11) is more Atlantic than the foregoing species. It was found at Möre in samples July 20th 1926. It was then present in moderate numbers in the 20—0 m. haul at Stations B, C, D and E. The maximum number, 511 specimens, was found at Station D. In all cases the number amounted only to 1 % of the stock of copepods in the haul concerned.

Chiridius armatus, Boeck, was not found as might be expected from Sars (03) at the deep stations in the fjord. The species was found only twice, viz. on May 12th 1926 and June 29th 1927, both at Station A in the 150—50 m. hauls. In each case there was only a small number, 71 and 57 specimens respectively.

Paracalanus parvus, Claus, has only been found with certainty twice in our

collection. 412 specimens were taken on August 11th 1925 at Station D and 558 specimens at Station C on March 28th 1927. The latter in the 60—20 m. haul. The species then constituted 2 and 3 % respectively of the stock of copepods in the hauls. According to all earlier investigations it rarely occurs in the Möre district. There is, however, a great probability that the species has been over-looked in the sample, if it is not present in that part where the determination of percentage is made. Moreover its copepodites can certainly be easily mistaken for the copepodites of *Pseudocalanus minutus*. *Paracalanus parvus*, is therefore probably more common in that district than investigations have hitherto been able to show, even though it scarcely plays any very important part in the plankton.

Pleuromamma robusta, Dahl, was found twice in deep hauls at Station E in 1927. The observations were the following: $^{28}/_{3}$, 400—200 m., 37 specimens 4 % and $^{1}/_{6}$, 100—50 m., 4 specimens, 1 % of the stock in the haul.

Rhincalanus nasutus, Giesbrecht. 14 specimens of this curious copepod were taken on July 22nd, 1925 off Storeggen in a tow net at a depth of about 100 m. The salinity was 36.37 ‰ and the temperature 9.25°, i. e. pure Gulf Stream water. The position was 63° 32′ north and 50° 39′ east. This is somewhat farther to the north than the the most northerly observations in the Norwegian Sea mentioned by Farran (10).[1])

Scolecithricella minor, Brady, is the most frequently occurring *Calanoid* of those mentioned here. In 1926 it was found once at Station A, 3 times at Station B and once at Station C, in five cruises in all from March 26th—27th to July 20th. In 1927 *Scolecithricella* was found at both stations in the fjord in all three cruises, and further three times at Station A, twice at Station D, and three times at Station E, i. e. in seven out of nine cruises. The dates were from March 1st—2nd to August 11th. The numbers were always small, the maximum being 126 at Station Ffj. on August 11th. As a rule *Scolecithricella* was found in the deepest hauls and rarely above 50 m. In one case, Station B April 9th 1926, the specimens, 46 in number, were taken in the haul 20—0 m.

Ætidius armatus, Boeck, was found (3 specimens) in the 100—50 m. haul at Station B March 26th 1926. Otherwise this copepod was not found in the area of our investigations.

2. Cyclopoida.

Oithona helgolandica, Claus.

Oithona helgolandica is one of the most common of the copepods occurring at Möre. It is Eurythermal and Euryhalin and belongs to the Epiplankton (Farran

[1]) During the printing of this paper my attention was drawn to a statement by Linko, that he has found a fullgrown specimen of *Rhincalanus nasutus* in 69° 57' north Lat. and 32° 24,5' east Long. (A. K. Linko: Unters. über das Plankton des Barents-Meeres: Wiss. prakt. Murmaneksp. St. Petersburg 1907 [in russian]).

Table 35. Number of *Oithona helgolandica* in the total Hauls at the Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1925	26-28/V	9088	3132	1820	..	..			2810
	22/VII	17511	11880						5878
1926	16-18/III	320	..	490	1040	..			370
	26-27/III	772	..	2169	237	423			900
	9-10/IV	957	700	460	1900	1003			1004
	28-29/IV	..	853	1910	2748	934			1089
	12/V	1697	675	732	3189	1644			1587
	1-2/VI	1396	1138	146	29	176			577
	24-25/VI	2056	1682	1074	2509	4380			2340
	20/VII	6356	4436	15817	15746	3729			9217
1927	1-2/III	568	168	107	361	106			262
	22/III						..	..	..
	28-29/III	385	1134	4038	3587	718			1970
	3-4/V	307	495	782	..	844			486
	1/VI	891	350	252	207	60			352
	21/VI					339	938	311	..
	29/VI	228	815	172	557	1067			569
	31/VII	5011	8622	13373	5624	3780			7482
	11/VIII						12142	4428	..

11). For that reason we find it at Möre spread over the whole Bank in varying numbers. It is lacking in the fjord on the first cruise in 1927, but was later found in large numbers right in to the innermost station.

Numerical Distribution.

1925.

Oithona helgolandica was found in 1925 in large numbers at Station E. The stock increased to double the number from the end of May to the end of July. On July 27th it amounted to 60 % of the stock of copepods in the haul at Station D.

1926.

In 1926 there were small quantities at the beginning of March but the stock steadily increased in numbers until May 12th when there was an average number of 1587 for the whole line of stations. The bulk of the stock the whole time was found at Stations D and C. On June 1st—2nd the number had slightly decreased and in that line there was an increasing number from Station A to Station E. Later on the stock increased again and reached its maximum height on July 20th. The maximum number in the two last cruises lay at Stations B and C respectively.

1927.

In 1927 the stock on the bank was also small at the beginning of March, and as previously mentioned this species was lacking in the fjord on March 22nd. However, as early as the end of March the species reached an average number of 1970, with a maximum at Station C. viz. 4038. The stock again decreased until June 1st as in previous years. A new maximum with the greatest height of the year was found on the bank on July 31st. Figures of the same dimensions were found in the fjord on August 11th. At Station Ffj. 64 % of the stock in the 50—0 m. haul were then *Oithona helgolandica.*

On the bank the percentage occurrence of *Oithona helgolandica* in the samples was large in the first cruise before *Calanus finmarchicus* had began to appear in mass, viz. from 12 % to 43 % in upper hauls. In April—May *Oithona helgolandica* was outnumbered by *Calanus finmarchicus* and the percentage is rarely over 10. In June and July the percentage again increases and in the latter month reaches values of between 14 and 32 %, and in the two previously mentioned cases even up to 60 and 64 %.

Vertical Distribution.

As previously mentioned *Oithona helgolandica* belongs to the Epiplankton. At Möre the largest number are usually found in the upper hauls from 20—0 m. or 50—0 m. It is also common and to some extent present in maximum numbers in the 50—20 m. haul. Below that depth it occurs frequently but always in small numbers. In August 1927 it was found in the fjord in the 400—150 m. haul, which is the greatest depth at which it has been found at Möre.

Both in 1926 and 1927 the number of *Oithona helgolandica* had two maxima with an intervening minimum. This is at any rate evident at Stations A, B and C and it was more marked in 1927 than in 1926. The first maximum occurred in the middle of May in 1926 and the end of March 1927. In the latter year, however, observations are lacking for April. The large second maximum occurred in July in both years, although nothing can be said as to whether the stock culminated or not. The variation in numbers was probably due to periodicity in breeding. Concerning this, however, we have no certain observations as no table was made regarding the stages of development in which the determined *Oithona helgolandica* were found.

The hydrographical conditions in which *Oithona helgolandica* is found are of minor interest on account of its Eurythermal and Euryhaline character.

Oithona spinirostris, Claus.

Oithona spinirostris is more southern and Atlantic in its occurrence than the foregoing species. It is not quite so common in our material as *Oithona helgolandica* but is nevertheless found in all cruises and with a few exceptions also at all stations.

It is lacking at Station C in 6 of the 15 cruises. The depth at that Station is 80 m., which is undoubtedly sufficient to explain the absence of the species there. The numerical distribution is shewn in the following table:

Numerieal Distribution.

Table 36. Number of *Oithona spinirostris* in the total Hauls at the Stations in 1925, 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1925	26-28/V	..	522	..	..	154			135
	22/VII	1344	198						773
1926	16-18/III	142	39	..	95	149			103
	26-27/III	96	..	..	16	..			28
	9-10/IV	..	..	..	46	31			15
	28-29/IV	1912	3033	929	3594	791			2023
	12/V	943	1910	394	1726	1279			1250
	1-2/VI	429	279	365	245	181			299
	24-25/VI	436	277	261	268	182			255
	20/VII	380	165	1280	943	444			642
1927	1-2/III	568	65	..	35	10			136
	22/III					23	84	191	..
	28-29/III	94	262	..	..	68			85
	3-4/V	239	366	297	341	409			328
	1/VI	1498	800	433	474	404			722
	21/VI					516	312	188	..
	29/VI	130	418	177	2395	570			738
	31/VII	1090	3010	3553	4631	1188			2694
	11/VIII						1341	114	..

In March the stock was small and even decreased in numbers from the beginning to the end of that month in both years. In 1926 the stock reached its maximum number at the end of April. It then decreased until the end of June, whereupon a slight increase in numbers occurred on July 20th. In 1927, on the other hand, to judge from the few cruises, there was a steady increase in numbers from March until July 31st. *Oithona spinirostris* was found in the fjord at all stations, and the number increased at Station Ffj. from March—August, but decreased in the same period at Station Rfj. In the fjord, however, regarded as a whole, there was a great increase. The maximum number in the stations on the bank was found in 8 out of 15 cruises at Stations E and D whilst in 7 cruises it was found at Stations A and B. The largest number observed at one station was found at Station B in both of the last two years.

Vertical Distribution.

Oithona helgolandica and *spinirostris* supplement each other in the vertical distribution, since the latter as a rule belongs to the deeper layers of water. Farran (11) found its most common occurrence at between 300 and 100 m. whilst Störmer (26) found that it occurred in largest numbers between 500 and 300. In the fjord where we have the greatest depths it is never found in any large numbers below 200 metres. Its maximum there lies between 200 and 50 m. Some were found in the 50—20 m. hauls and the 50—0 m. hauls respectively, but none in the 20—0 m. hauls.

I have already mentioned that the depth at Station C on the bank, viz. 80 m. appears to be too small for its common occurrence, at that Station. In certain cases *Oithona spinirostris* was found in 1926 above 20 m., viz. in 12 out of 34 hauls from 20—0 m. It was, however, rarely in large numbers. The maximum number at 10 out of 34 stations was found in the 50—20 m. haul, but otherwise below 50 m. In 1927 the maximum number in only four out of 30 cases was above 50 m., whilst otherwise the maximum lay below that depth. There does not appear to be any law for the difference in vertical distribution with regard to the time of the day.

Spawning of *Oithona spinirostris* in the Möre district has not been found. If the species is stationary in the fjord, which does not appear to be unreasonable, spawning must take place, at any rate, on a minor scale. In the existing material the large stock on the bank shews no regular deviation in numbers similar to that which is the case for most of the species which spawn in that district. As, according to Farran (11) and Sars (18), *Oithona spinirostris* at Möre is close to its northerly limits in Norwegian waters, it will also not appear to be reasonable that breeding should take place on any large scale. In that case the stock must also mainly depend upon immigration from the spawning districts lying more to the south and west.

Oithona spinirostris at Möre is found in temperatures varying between 4.2° and 12.0° and salinity between about 33.0 ‰ and 35.3 ‰. This lies within the limits known in respect of other waters (Farran 11).

Copepodites of Oithona sp.

In the large collection from 1926 and 1927 the smallest copepodites of *Oithona* species were not determined as regards species on account of the time such work would have required. The distribution of these copepodites in time and place with regard to numbers is such that is not possible to decide with certainty whether they principally belong to one or another species. This, of course, considerably diminishes the value of the copepodite collection, when the species from a biological point of view may belong to such widely different copepods. For that reason we will not go into details here but restrict ourselves to certain general features.

Table 37. Number of *Oithona* Copepodites in the total Hauls at the Stations in 1926 and 1927.

Year	Date	St. E.	St. D.	St. C.	St. B.	St. A.	St. Ffj.	St. Rfj.	Average
1926	16-18/III	320	819	182	756	1494			714
	26-27/III	36	..	..	87	234			89
	9-10/IV	—	—	104	46	—			30
	28-29/IV	2410	2159	2360	1288	—			1643
	12/V	2248	2223	2289	4445	2558			2759
	1-2/VI	1866	1007	347	453	3105			1356
	24-25/VI	988	2075	1684	3264	5979			2798
	20/VII	7935	3121	8807	11401	364			6326
1927	1-2/III	710	319	291	202	205			345
	22/III					45	198	202	..
	28-29/III	2930	1882	—	—	266			1016
	3-4/V	1771	1677	3122	1485	3722			2356
	1/VI	1498	800	433	474	307			702
	21/VI					518	1807	863	..
	29/VI	1202	737	1457	5139	3352			2377
	31/VII	4231	9742	14924	20665	12948			10502
	11/VIII						3870	3336	..

Numerical Distribution.

As in the case of the two species of *Oithona*, the number of copepodites is small in March and April. In both years there were two maxima in numbers, one in May and another in July. The average in May was 2700 and 2400 in 1926 and 1927 respectively, and in July 6300 and 10500. In 1927 there were copepodites in the fjord at all stations in all cruises, increasing in numbers from about 200 in March to about 3600 in August. The presence of copepodites in the fjord in March appears to indicate that they belong to *Oithona spinirostris*. The maximum number in the various cruises is such that the bulk of the stock of copepodites belongs to the coast water at Stations A and B. The distribution on the bank both as regards time and place, on the whole mostly resembles that of *Oithona helgolandica*. In that case there should be a mixed population of copepodites, even though the greater part presumably belong to *Oithona helgolandica*.

These copepodites were found at all depths in both years, but not below 150 meters in the fjord. The maximum number, however, was always found above 50 meters, and in 1926 in some cases also above 20 meters.

Oncæa borealis, G. O. Sars.

This copepod was found in 7 out of 8 cruises in 1926, in 3 out of 6 cruises on the bank, and in 2 out of 3 cruises in the fjord in 1927. The numbers were

always small. It occurred most abundantly at Station A being found 7 times, numbers between 13 and 195 specimens. It was present in the fjord in the deep hauls at both stations in the two first cruises. It was twice found at Station B in 1926, three times at Station D and twice at Station E. *Oncæa borealis* was taken at all depths on the bank but there was a distinct maximum occurrence below 50 meters. It was not found in the fjord above 50 meters.

Other copepods of Cyclopoida were not found in the samples of plankton at Möre. It is, however, quite possible with the method employed that small and rare forms are overlooked in large samples.

3. Harpacticoida.

Microsetella norvegica, Boeck.

Microsetella was only found once in our collection, viz. at station E July 31st, 1927. 28 specimens were found in a haul taken 200—50 meters deep. Gran (02) and Sars (11) mention that it is common and plays a certain part in our oceanic plankton. They always found it near the surface but in our case it was taken below 50 meters. It is rather surprising that it has so rarely been observed in our collection, but it is so small that it easily passes through the cylindrical part of our net. On account of its narrow breadth it can also pass through the conical part of the net. Moreover there are the errors due to the method employed so that it is easy to explain why it has not been discovered more frequently.

Summary.

1) Samples of zooplankton were collected at Møre, on the west coast of Norway, in the years 1925, 1926 and 1927. There were taken regular cruises, in 1926 every second week and in 1927 every month from March to August. Each cruise consisted of a line of 5 fixed stations, called Stations A, B, C, D and E from the inshore waters and out to Storeggen, the slope of the coastal bank. All the samples here described were taken in vertical hauls at definite depths with a standard closing net. The samples were immediately fixed with 7 per cent formalin. This paper deals only with the copepods. The gravimetric method by Hjort and Ruud (27) was used in the analysis of the samples.

2) The total number of copepods as well as the composition of the copepod community was found to vary in a similar way for the three years. The total stock of copepods was from 2,000—6,000 specimens per station in the beginning of March. In April-May the number of copepods had increased to an average of 30,000. From thence there was a decrease in number to the beginning of June, the stock then being below 15,000 specimens per station. Later on the average

number increased to 35,000 or 40,000 in July-August. The percentage figure for the different species of copepods varied in a similar way. In March about 15 per cent. of the stock was found to be *Calanus finmarchicus*. The percentage figure for this species increased to 65 per cent. in April and decreased to 40 per cent. in July. In accordance with this we also find a close agreement between the total stock of *Calanus finmarchicus* and the volumes of zooplankton found. The average volumes per station varied from 2 to 3 c.c. in March to 50 c.c. in April-May.

3) *Calanus finmarchicus* is the most important species in these waters. There were found to be two maxima in the total figures for this species. On analysing the composition of stages in the stock of *Calanus finmarchicus*, these two maxima were found to correspond to two spawning periods, one in February-March and one in May-June. The spring period of reproduction is the major one, as also found in other waters (Bigelow, 26). There is only a slight difference in this condition from 1926 to 1927, e.g. a displacement in time and small differences in numbers.

4) "Stock curves" have been worked out for *Calanus finmarchicus*, showing the composition of stages at each station from each cruise in 1926 and 1927 (Fig. 4 and 5). From these curves it will be seen that the spawning commences in inshore waters and proceed seawards. The stock curve at Storeggen is of a somewhat different character to those on the coastal bank, due more or less to an immigration of *Calanus finmarchicus* from localities outside the area investigated. We therefore assume that *Calanus finmarchicus* has two centres of reproduction, one in inshore waters and one at Storeggen, as Gran found to be the case with the reproduction of diatoms (Gran, this volume).

5) As the coastal water continuously drifts northeastward we assume that the older stages of *Calanus* found on the coastal bank were spawned to the southwest. Taking this into consideration we find that *Calanus finmarchicus* in these waters requires ca. 3 months for its entire development.

6) Samples collected on long cruises, one each year, some 200 miles to northwest and in addition to these samples from the "Michael Sars" Expedition 1924 were analysed. There was found to be a minimum stock of *Calanus* in the central part of the Gulf Stream, while this species was much more numerous towards the coast and towards the Norwegian Sea. The composition of the stock outside the Gulf Stream was in summer very similar to that found in coastal waters in April-May.

7) Three cruises were taken into the Romsdalsfjord in 1927. There was found a constant stock of a more local character than that found on the coastal bank.

8) Several measurements of *Calanus finmarchicus* were undertaken and show in accordance with previous authors that *Calanus* from a minimum winter length

increases to a maximum length in the early summer. The length composition of individuals in Stage V also shows that the assumption of one stock of *Calanus* in the coastal waters and one at Storeggen might be made also from this point of view. There was also found a close correlation between the length of *Calanus* and certain hydrographical conditions, e.g. the temperature.

9) The vertical distribution of the different stages of *Calanus finmarchicus* was investigated and found to be in accordance with previous observations, i.e. the younger stages were exclusively found in the upper layers and only Stages V, VI ♀ and VI ♂ were found in considerable numbers in deeper or intermediate depths.

10) *Calanus finmarchicus* was only found in water of temperatures lying within the limits given by Farran (11). The extreme temperatures found were 2,99° and 13,42°. The lower limit of salinity given by Farran is certainly too high. At Møre *Calanus finmarchicus* was found in salinities from 32,43 ‰ to 35,32 ‰. Damas (05) states that spawning takes place in water with a temperature 4°—6° and salinity 34,90 ‰. The limits of temperatures and salinities for spawning in the Møre region were found to be from 4°—7,5° and 33 ‰—35,10 ‰.

11) In a similar way as with *Calanus finmarchicus*, but not so thoroughly, we investigated several other copepods.

Calanus hyperboreus was found to be stationary in the fjord, chiefly in the deeper parts. It spawns in February-March.

Euchæta norvegica is always to be found in the deep fjord and also occasionally at Storeggen where it possibly immigrates from the deep sea. Spawning was found both in March and June in the fjord, in March, however, females with ovisacs were most frequent.

Metridia longa is common in the fjord and at Storeggen. It was always taken deeper than 50 m. It seems probable that *Metridia longa*, like the two previous species, breeds in the fjord and is stationary there, though we have no definite observations on this point.

Metridia lucens is scarcely found in the fjord but is numerous in the samples taken just outside the skerries and at Storeggen. As was the case with *Calanus finmarchicus* there are presumably two centres of distribution, one in the coastal waters and one in the rich border layers against the Gulf Stream.

There were found in the samples many younger copepodit stages of *Metridia* sp. which probably belong to *Metridia lucens*.

Acartia Clausi and *Acartia longiremis* were found to supplement each other, the former being found chiefly outside the shallow part of the coastal bank while the latter were found chiefly in more inshore waters. The stock of both species was considerably richer in 1926 than in 1927. Both species certainly spawn twice in these waters, the first time in March-April and the

second time in May. Whether the species also spawns later in the summer cannot be said with certainty.

Microcalanus pygmæus is always found in the deeper hauls both in the fjord and on the bank. The stock was also in this case richer in individuals in 1926 than in 1927. In all probability *Microcalanus* breeds in March and in May-June.

Pseudocalanus minutus is next to *Calanus finmarchicus* certainly the most important copepod in our samples. This copepod also spawns twice in the area investigated, but the second spawning in July seems to be the chief one, the numbers of the species increasing greatly in the summer months. However, adult males are found during the whole period of investigation, from which we may possibly assume a continuous spawning for these species. Only exceptionally was *Pseudocalanus* found below 50 m. in the Møre region.

Temora longicornis is commonly found in the summer at the innermost stations. This species is not stationary in the area investigated, but is carried along the coast to Møre with the Baltic Stream. Breeding at Møre has not been actually observed.

Eight species of Calanoids are recorded as found more or less accidentally, and always in small numbers.

Oithona helgolandica and *Oithona spinirostris* were found during the whole period investigated, in great numbers, chiefly in the summer months.

The two species supplement each other in vertical distribution, *Oithona helgolandica* being always found in the upper layers.

Oncæa borealis was found occasionally in all three years, always in small numbers.

Microsetella norvegica was the only Harpactocoid found in the samples, and it was only found once, viz. at Storeggen in July 1927. This species easily passes through the meshes of our net, a fact which explains why it has not been found more frequently.

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